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AN ACCOUNT OF CERTAIN TESTS OF THE TRANSVERSE STRENGTH AND STIFFNESS OF LARGE SPRUCE BEAMS.

[An address delivered before the American Society of Mechanical Engineers on November 3, 1882.]

By GAETANO LANZA.

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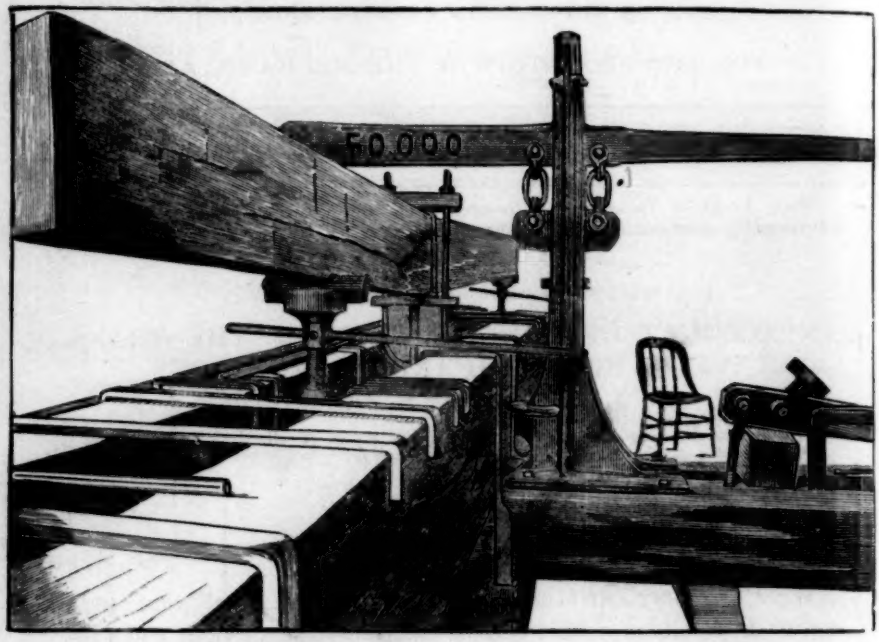
MR. PRESIDENT AND GENTLEMEN:—I beg leave to call your attention to the results of certain tests of the transverse strength and stiffness of full size spruce beams, carried on by members of my classes in my laboratory at the Massachusetts Institute of Technology. The machine with which they were made is a 50,000 pounds machine, and is capable of testing beams twenty-five feet long and under, as well as many of the framing joints used in practice.

It consists, as shown in the cut, of a compound lever, hung in a cast iron frame, to which is connected, by means of a steel rod and turn buckle, one end of a lever, of equal arms, placed below, this lever having a 12-inch leverage, and being connected at its other end by means of a chain, with the yoke shown in the cut. Two hard pine beams, each 20 inches deep, 10 inches wide and 26 feet long, are laid across the timbers of the machine in such a way that the chain

already referred to is midway between them. Two common jack screws, each in a pair of wrought iron stirrups, are placed at a distance apart depending upon the span of the beam to be tested, the latter being placed, as shown in the cut,* upon the jack screws, and under the yoke. The jack screws are then screwed up, and the beam to be tested is thus raised at its two ends, and hence loaded at the point where the yoke is attached.



It was in operation about two months, last session, and has been in operation about one month, this present session. During that time we have tested about thirty specimens for breaking strength, and about fifteen for deflection. The breaking has been effected as rapidly as could be done, consistently with the determination of the deflections, and the deflections under various loads were measured within a very short time after the application of the loads. In short, no experiments have thus far been carried on to determine the effect of time upon these quantities, though some will be made very soon. It was also deemed best to keep to one kind of timber, until we should have a sufficient number of tests to warrant us in drawing a conclusion as to

* [We are indebted to the *Boston Journal of Commerce* for the use of this cut.]

No. of test.	Width and depth in inches.	Distance between supports. Ft.	In.	Manner of fixing the ends and loading.	Breaking weight in pounds.	Modulus of rupture in lbs. per sq. in.		Modulus of elasticity in lbs. per square inch.	Remarks.
1	2 x 12	6	8	Framed at ends	6,504				
2	4 x 12	6	8	Header	10,338				
3	2 x 12	15		Load at middle	5,894	5,526		1,237,215	
4	2 x 9	6	7·5	" "	7,322	5,389		1,067,893	
5	2 x 12	15		" "	5,586	5,237			
5(a)	2 x 12	7		" "	8,982				
6	2·75 x 9	6	8	" "	7,586	4,082		938,453	
7	3 x 9	4		" "	11,086	3,285			
8	3 x 9	10		" "	6,086	4,508			
9	3 x 9	15		" "	5,086	5,651			
10	3⅛ x 12	20		" "	6,586	4,253			
11	2·5 x 13·5	10		" "	9,585	3,787			
12	3·75 x 12	16		Load 4·5 ft. from one support	7,585	3,271			
13	3·75 x 12	16		Ditto, mortised	9,085				
14	7 x 2	7		Load at middle	1,944		8,748		Selected stock.
15	1·75 x 6·75	7		" "	4,785		7,562		
16	3 x 9	6	8	" "	9,985	4,931			
17	3 x 9	6	8	Load at 4 points, 16 ins. apart	16,744	4,961			
18	3·9 x 12	16		Load 4·5 ft. from one support	12,585	5,218			
19	2 x 12	14		Load at middle	4,404	3,854		1,482,645	
20	2 x 12	14		" "	5,108	4,469		1,588,548	
21	3⅛ x 12	14		" "	8,627	3,834		1,187,074	
22	3⅞ x 12	14		" "	12,545	5,666		1,332,715	
23	3⅞ x 12¾	14		" "	6,917	2,995		897,961	
24	3 x 11⅞	14		" "	8,927	5,442		1,572,470	
25	2 x 9¾	14		" "	3,198	4,239		1,460,629	
26	2¾ x 12	14		" "	6,819	4,339		1,398,667	
27	1⅛ x 10	14		" "	4,306	5,601		1,355,860	
28	4⅛ x 12	18		" "	8,829	4,816		1,397,136	
29	4 x 12⅛	18		" "	8,324	4,586		1,259,224	
31	3⅛ x 12	18		" "	7,721	5,559		1,231,498	
						25)115,499		15)19,405,978	
						Av. mod. of rupture =	4,620	Av. mod. of elast. =	1,293,732

the average value of the modulus of rupture, and of the modulus of elasticity of that kind of wood; and spruce was selected, as a wood that is very much used in building. Experiments are now in progress in my laboratory to determine the same quantities for yellow pine.

The results that were obtained last session are shown above the double line in the accompanying table, and those obtained this present session, below.

At the beginning of this session these tests were continued, with the following objects in view:

1. Inasmuch as the lumber had, last session, been selected either by a carpenter, without reference to testing, or had been simply ordered at the yard, directions being given to the dealer to send merchantable stock, it seemed best that I should go to the yards myself and select from the piles some of the best and some of the average of what was on sale as merchantable stock, and thus that we should be able to speak with certainty about the values of the modulus of rupture and modulus of elasticity of such lumber.

2. Inasmuch as last year we had had only three determinations of the modulus of elasticity, it was desirable to obtain more values, and thus to be able to determine an average value.

3. It was desirable to see how far, in the light of what had already been done, we should be able to judge of the modulus of rupture by simply inspecting a piece of timber, and to endeavor also to train the students, to some extent, to have this ability.

That the values of the modulus of rupture which we have obtained should differ very considerably from those given in our text-books and engineers' handbooks, and deduced from tests of small pieces, I need not tell a company of engineers; but, as you may not carry in your minds the precise figures given by different authorities for the modulus of rupture of spruce, I will place them here:

Hatfield gives as mean value,	.	9,900	lbs. per. sq. in.
Rankine, "	" .	11,100	"
Laslett, "	" .	9,045	"
Trautwine, "	" .	8,100	"
Rodman, "	" .	6,168	"

Trautwine advises for use to deduct one-third in the case of knotty and poor timber.

As a result of the tests thus far made in my laboratory, it seems to me safe to say, that if our Boston lumber yards are to be taken as a fair sample of the lumber yards in the case of spruce, that if such lumber is ordered from a dealer of good repute, no selection being made except to discard such pieces as might be classed as culled timber, *i. e.*, that which is rotten or has holes in it, that 3000 pounds per square inch is all that could with any safety be used for modulus of rupture, and even this might err in some cases, in being too large. 2. That if the lumber is carefully selected at any one lumber yard, so as to take only the best of their stock, it would not be safe to use for modulus of rupture a number greater than 4000, and if we required a lot of spruce lumber which should have a modulus of rupture of 5000 it would be necessary to select a very few pieces from each lumber yard in the city.

Next, as to the modulus of elasticity: until the beginning of this session we had made only three experiments on this subject, and these gave as an average 1,081,187; those made this autumn have contributed to raise this value somewhat, as will be seen from the table, where we obtain an average of 1,293,732.

Of course it is naturally to be expected that time tests will give much smaller values for both modulus of rupture and modulus of elasticity.

As to the variations of the values shown in the table, they are considerable, and depend upon the quality of the lumber, *i. e.*, upon the number and location of the knots, the shakes and cracks that are so commonly found at the heart of timber, also upon the degree of seasoning, although it is my opinion that the increase of strength due to this latter item has often been over-estimated. Knots near the middle of the span act very prejudicially, whether they are at the top or at the bottom, and by saying near the middle of the span I mean to include a very considerable range. It is impossible, however, to describe the mode of judging correctly, from inspecting a stick, what will be its modulus of rupture, and this ability can only be acquired by practice, and this very practice is one of the benefits that it is hoped to enable the students to gain to a greater or less degree.

As to the relation between the modulus of rupture and the modulus of elasticity, whilst it is generally true that those pieces that have a high value of the one have a high value of the other, and *vice versa*, nevertheless, I have not been able thus far to form any definite idea of

the connection between them, at least such as to enable one to attempt to predict the modulus of elasticity from the appearance of the piece. Perhaps further experiments may satisfy this want, and as to the desirability of satisfying it no one can have any question, for the stiffness of beams is, or ought to be, as prominent a question to builders as their breaking strength.

We have already made three, and shall make quite a number of experiments on the strength of framing joints, such as headers, trimmers, etc., in regard to which we have thus far been entirely devoid of any experimental knowledge.

As to the method of fracture: while the most usual fractures in spruce beams have occurred either by tension or compression, or a combination of the two; nevertheless in some cases the beams have been split from the middle to one end, along or near the neutral axis; and while the experiments where this kind of fracture has occurred are not sufficient in number to warrant definite conclusions as yet, nevertheless it is an element that is forcing itself very strongly upon our attention as one that must be taken into account in practice.

A noticeable instance of this kind is to be found in the case of beam No. 22, another in beam No. 24, and a third in beam No. 31, which gave way in that manner.

At the meeting a number of photographs of the fractures obtained were exhibited and commented upon.

Table of Tests.

The following are the records of the tests made during the first month of the present session by students in the Department of Applied Mechanics of the Massachusetts Institute of Technology. In these tables, as far as the deflections are concerned, the first load is assumed as the start point, the deflection under that load being counted zero.

The deflections are recorded to the 10,000th of an inch, as the measurements were made with a micrometer screw that could be read to that degree of accuracy, and hence it was thought best to give the results as they were obtained, although it is not claimed that change of temperature or other disturbing causes, which would be inappreciable as far as any practical result is concerned, may not cause so great a variation as to render it unnecessary to read to such a degree of accuracy.

The spruce, with the exception of Nos. 22 and 23, was cut in the spring of 1882, and brought from Bangor, Me. Nos. 22 and 23 were

cut in 1881. The students making the tests, hand in the reports of the same, and make the necessary computations of modulus of rupture, modulus of elasticity, etc. The values given in the tables have been re-computed by my assistant, Mr. Edward F. Ely.

The number given as the "Max. intensity of shear at neutral axis" is that which would be obtained by computing it from the breaking load in accordance with the ordinary theory of beams.

No. 19.—Spruce Joist, 2 in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
686	·0473	·0473	Rested over night.
510	.....	.....	Load on next morning.
485	·0000	.....	Began new set of readings.
686	·0343	·0343	
887	·0825	·0482	
1,088	·1284	·0459	
1,088	·1309	.....	After 1 hour.
1,289	·1764	·0455	
3,000	.....	.....	Cracks opened near centre above neutral axis.
4,103	.....	.....	Bulging on east side at top. At centre top slewed to west.
4,404	.....	.....	Breaking load.

Fracture occurred within an hour after application of breaking load.

Line of fracture followed the knots.

Modulus of rupture = 3,854 lbs. per square inch.

Mean deflection for 201 lbs. = ·0465.

Modulus of elasticity = 1,482,645 lbs. per square inch.

Maximum intensity of shear at neutral axis = 138 lbs. per square inch.

No. 20.—Spruce Joist, 2 in. by 12 in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
686	·0431	·0431	
887	·0885	·0454	
1,088	·1303	·0418	
5,813	.....	.....	Twisted badly in spite of bracing, and load fell off rapidly, it being impossible to keep this load on.
5,108	.....	.....	Breaking load.

Modulus of rupture = 4,469 lbs. per square inch.

Mean deflection for 201 lbs. = ·0434.

Modulus of elasticity = 1,588,548 lbs. per square inch.

Maximum intensity of shear at neutral axis = 160 lbs. per square inch.

No. 21.—Spruce Joist, $3\frac{15}{16}$ in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
686	·0000		
1,088	·0546	·0546	
1,490	·1033	·0487	
1,892	·1654	·0621	
2,291	·2192	·0538	
2,690	·2858	·0666	
3,098	·3397	·0539	
3,500	·4039	·0633	
3,902	·4644	·0614	
4,304	·5256	·0612	
4,706	·5898	·0642	Left over night.
4,208	.5845	.....	Next morning.
4,706	·6529	.....	Load increased to 4,706 again.
4,404	.....	.....	Next day.
5,610	.....	.....	Braced the stick.
8,627	.....	.....	Breaking load after carrying 15 minutes.

Modulus of rupture = 3,834 lbs. per square inch.

Mean deflection for 402 lbs. = ·0590.

Modulus of elasticity = 1,187,073 lbs. per square inch.

Maximum intensity of shear at neutral axis = 137 lbs. per square inch.

No. 22.—Spruce Joist, $3\frac{7}{8}$ in. by 12 in. Span 14 feet. Loaded at centre. Lower part of tree. Very free from knots. Had been seasoning on the wharf about one year.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0534	·0534	
1,289	·1052	·0518	
1,691	·1583	·0531	
2,495	·2665	·1082	
3,299	·3748	·1083	
4,103	·4810	·1062	
4,907	.....	.....	Left over night.
4,203	.....	.....	Next morning.
12,545	.....	.....	Breaking load. Beam broke by tension and afterwards by shearing along the neutral axis. Shear extended from centre to one end, and pieces slid by one another about $\frac{7}{16}$ inches.

Modulus of rupture = 5,666 lbs. per square inch.

Mean deflection for 402 lbs. = ·0534.

Modulus of elasticity = 1,332,715 lbs. per square inch.

Maximum intensity of shear at neutral axis = 202 lbs. per square inch.

No.23. —SPRUCE JOIST, $3\frac{7}{8}$ in. by $12\frac{1}{4}$ in. Span 14 feet. Loaded at centre. Upper part of same tree as No. 22. Very knotty. Had been seasoning on the wharf about one year.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0819	·0819	
1,289	·1457	·0638	
1,691	·2204	·0747	Left over night.
1,425	.....	.....	Next morning.
1,691	·2569	.....	Raised load again.
2,093	·3269	·0700	
2,495	·4017	·0748	
2,897	·4828	·0811	
3,299	·5536	·0708	
4,103	·7073	·1537	
4,907	.....	.....	Left on for half an hour, during which time load fell off to 4,436; beam splitting and cracking at a large knot on lower edge near centre of span.
6,917	.....	.....	Breaking load (knot causing break about 15 inches from centre).

Modulus of rupture = 2,995 lbs. per square inch.

Mean deflection for 402 lbs. = ·0745.

Modulus of elasticity = 897,961 lbs. per square inch.

Maximum intensity of shear at neutral axis = 108 lbs. per square inch.

No. 24.—SPRUCE JOIST, width $3\frac{1}{16}$ in. at bottom, $2\frac{7}{8}$ in. at top, depth $11\frac{7}{8}$ in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0003	·0003	
1,289	·1247	·0644	
1,691	·1835	·0588	
2,093	·2485	·0650	Left 15 hours, when load had fallen to 1,766 lbs.
2,093	·2742		
2,495	·3285	·0543	
2,897	·3870	·0585	
3,299	·4521	·0651	
3,701	·5189	·0668	
4,103	·5746	·0557	
8,927	.....	.....	Breaking load. Broke by shearing along neutral axis. Split opening about $1\frac{1}{2}$ inches.

Modulus of rupture = 5,442 lbs. per square inch.

Mean deflection for 402 lbs. = ·0610.

Modulus of elasticity = 1,572,470 lbs. per square inch.

Maximum intensity of shear at neutral axis = 190 lbs. per square inch.

No. 25.—SPRUCE JOIST, 2 in. by $9\frac{3}{4}$ in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1625	·1625	
1,289	·3342	·1717	
1,691	·5280	·1938	
3,198	.....	....	Breaking load, by compression at top and tension at bottom.

Modulus of rupture = 4,239 lbs. per square inch.

Mean deflection for 402 lbs. = ·1760.

Modulus of elasticity = 1,460,620 lbs. per square inch.

Maximum intensity of shear at neutral axis = 123 lbs. per square inch.

No. 26.—SPRUCE JOIST, $2\frac{3}{4}$ in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0534	·0534	
1,691	·2050	·1516	
2,495	·3610	·1560	
3,299	·5025	·1415	
5,610	.....	.....	Cracked somewhat.
5,713	.....	.....	Cross-grained fibre at bottom tore apart.
5,914	.....	.....	A sharp crack was heard and a long split appeared.
6,819	.....	.....	Breaking load.

Modulus of rupture = 4,339.

Mean deflection for 402 lbs. = ·0718.

Modulus of elasticity = 1,396,667 lbs. per square inch.

Maximum intensity of shear at neutral axis = 155 lbs. per square inch.

No. 27.—SPRUCE JOIST, $1\frac{5}{16}$ in. by 10 in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1724	·1724	
1,289	·3272	·1548	Beam tipped and braces were put in at ends beyond the straight edges.
1,691	·5441	·2169	Wedge was used on west side to keep straight edge close to the beam.
4,306	.....	.....	Breaking load.

Modulus of rupture = 5,601 lbs. per square inch.

Mean deflection for 402 lbs. = ·1814.

Modulus of elasticity = 1,355,860 lbs. per square inch.

Maximum intensity of shear at neutral axis = 167 lbs. per square inch.

No. 28.—SPRUCE JOIST, width 4¼ in. at bottom, 4 in. at top, depth 12 in. Span 18 feet. Loaded at centre.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1049	·1049	
1,691	·2999	·1950	
2,495	·5030	·2031	
3,299	·7033	·2003	
3,701	·8136	·1103	
4,103			
8,829	.....	.....	Breaking load.

Modulus of rupture = 4,816 lbs. per square inch.

Mean deflection for 402 lbs. = ·1017.

Modulus of elasticity = 1,397,136 lbs. per square inch.

Maximum intensity of shear at neutral axis = 134 lbs. per square inch.

No. 29.—SPRUCE JOIST, 4 in. by 12⅛ in. Span 18 feet. Loaded at centre.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1048	·1048	
1,289	·2169	·1121	
1,691	·3267	·1098	
2,093	·4424	·1157	
2,495	·5488	·1064	
2,696	·6227	·0739	
2,897	·6768	·0541	
6,917	.....	.....	Slight cracks heard.
8,324	.....	.....	Breaking load.

Modulus of rupture = 4,586 lbs. per square inch.

Mean deflection for 402 lbs. = ·1128.

Modulus of elasticity = 1,259,224 lbs. per square inch.

Maximum intensity of shear at neutral axis = 129 lbs. per square inch.

No. 31.—SPRUCE JOIST, 3⅛ in. by 12 in. Span 18 feet. Loaded at centre.

Tested by Messrs. Davis and Morse.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1486	·1486	
1,289	·3030	·1544	
1,691	·4514	·1484	
2,093	·6129	·1615	
2,495	·7615	·1486	
3,701	.....	.....	Cracking commenced.
7,721	.....	.....	Breaking load. Broke suddenly by compression of top fibres and shearing along the neutral axis. Split showed several small pin knots, running vertically in the beam, and apparently pinning the sides of the fracture together.

Modulus of rupture = 5,559 lbs. per square inch.

Mean deflection for 402 lbs. = ·1523.

Modulus of elasticity = 1,231,498 lbs. per square inch.

Maximum intensity of shear at neutral axis = 154 lbs. per square inch.

Fracture of Steel.—Ruptures often occur in steel, which are very difficult to explain. They are generally attributed to inequality in cooling or to imperfect annealing, but some experiments, which have been reported to the institution of naval architects, seem to show that the fractures are always attributable to a defect in the quality of the steel before rolling, and not to the inequality of the strains to which it is finally subject. When a piece of sound steel plate was heated to redness, and then cooled unequally by scattering water on various parts of the heated surface, it was hammered in various ways and submitted to a series of experiments of the most trying character, without giving any indication of fracture.—*Chron. Industr.*, No. 39. C.

THE ABSTRACTION OF HEAT BY MECHANICAL ENERGY.*

By JOHN ROWBOTHAM.

[A paper read at the stated meeting of the Franklin Institute, November 15, 1882.]

It is now a well-established fact that "Heat is Energy," and that one British thermal unit corresponds to 772 foot pounds of mechanical energy; but in the sequel we will endeavor to show that mechanical energy is also extensively used for the purpose of producing cold, or *abstracting* heat.

We do not propose going deeply into the theory of this process, but will merely confine ourselves to certain practical points, and state principally what has come under our immediate and personal observation.

In this particular latitude where crops of *natural ice* can, during the winter months, be gathered, the production of cold by its use is comparatively easy, although even here it is not always inexpensive; nor is the atmosphere thus obtained always the most desirable, viz.: where a *dry* atmosphere is required.

For certain purposes, however, the production of cold by means of ice has the advantage of simplicity; for instance, the confectioner will fill a metallic vessel, or can, with cream, and by surrounding it with broken ice, freely sprinkled with common salt, will soon freeze the cream; the plumber in repairing a water-pipe, to make a joint or new connection, to avoid digging up the street to reach the "ferrule" connection at the "main," or stopping off of the water in the main pipe, will first get at the point where the work is to be done, stopping the flow of water through the pipe by closing all the outlets, then by covering it with ice and salt, on the pressure side of the point to be worked at, in a very short time finds the water sufficiently frozen to enable him to complete his work.

In the cases cited the object sought was to get rid of a certain amount of heat; but paradoxical as it may seem to many, the railway-man will use the same process—mixing salt and snow to prevent ice from forming and remaining upon the tracks, curves, and switches. Com-

* It may be unnecessary to state that wherever in this paper the term "Production of Cold" is used, a corresponding "Abstraction of Heat" is meant, since "cold" though a popular expression, is in reality the absence of heat. [THE AUTHOR].

mon as these practices are, comparatively few who adopt them can clearly give the reasons for the effect produced.

The low temperature obtained in these cases is simply due to the capacity that certain substances have, when mixed together, of lowering the temperature of the melting point of the mixture. This is taken advantage of by the railway-man, who, by salting the snow, lowers the freezing temperature to about 0° Fahr. instead of 32°; but in melting, every pound of ice will take up as much heat as would raise a pound of water through 142°, and this serves the object of the confectioner and plumber—the heat required to melt the ice and salt being supplied in the one case by the cream, and in the other by the water in the pipe.

We know that in the greater portion of the globe, ice is not produced naturally, and that the cost of transportation makes it too expensive for general use, hence it is a luxury only to be indulged in by the wealthy; but inasmuch as the habits of all the people of the earth appear to be undergoing a radical change, through the rapid advancement of civilization, we predict that the time is not far distant when *ice* and *cold* will be considered as much of a necessity as *heat*, and this demand, in certain localities, must be supplied by artificial means.

The process of producing cold artificially, depends principally on the property of gases and vapors to become heated by compression, and cooled by expansion, and although this property was previously known, no definite relation between temperature and pressure, on which to base a calculation, had been established until Gay Lussac, at the beginning of the present century, found by a series of careful experiments, a mathematical expression for it; the truth of his conclusions has since been fully verified, by the experiments of Regnault and other scientists.

Lately a number of practical machines have been constructed in England based on this property of gases, and using atmospheric air as the means to produce cold, of which the "Giffard," the "Piggot," and the "Bell-Coleman" machines may be cited as illustrations; the last named being the pioneer in a new branch of trade, that of carrying fresh meat from New Zealand to London by sailing-ship. One hundred and seventy-five tons of meat were taken on board and frozen at the rate of ten tons per day, being at the time stowed away in the hold of the ship; the temperature below deck was always maintained below the freezing point whilst loading, and also during a voyage of ninety-eight days.

In these machines the air is compressed, by powerful steam engines, to a pressure of about two and a half atmospheres, its temperature rising to about 218° Fahr., depending on the temperature of the air to be compressed; it then passes into a "condenser" or vessel, where cold water is circulating, and by which the heat of the air is removed. The pressure of the air after cooling will still be considerable, and it is made to perform work in an expansion cylinder, the pressure falling to that of the surrounding atmosphere, and the temperature to about 35° below 0°. It is now expelled, and will be capable of taking up an amount of heat, equal to that removed from it by the circulating water, this heat being supplied by the objects to be frozen. These machines, though simple and capable of producing a low temperature, are not considered very satisfactory; this is due principally to the low specific heat of air, 50 cubic feet being required to cool one pound of water (a pint), degree for degree, which may be stated, the same quantity of heat will raise 50 cubic feet of air through as many degrees as it will 27 cubic inches of water. This necessitates very cumbrous machinery, and a corresponding waste of energy to accomplish a given result.

Their failure in practice is also due, in a great measure, to mechanical difficulties not easily overcome; they require large and easily worked, yet thoroughly air-tight, pistons and valves—conditions not readily attainable; and, moreover, the cold produced in the expansion cylinder congeals the moisture of the air, which, besides obstructing the passages, is equivalent to so much waste of energy, since the cold here produced cannot generally be utilized.

In this country, and in some of the countries of Europe, air machines have not been used to any great extent. Machines using some chemical, or liquid whose boiling point, at the pressure of the atmosphere, lies generally below the average atmospheric temperature, having been found more effective. In fact, in the first machines by which ice was successfully made to any extent, ether was the agent by which the heat was abstracted.

In 1850 to 1853, Professor A. C. Twining, of Hudson, Ohio, succeeded in practically demonstrating the feasibility of this process, and in 1858 an inventor named Harrison, of Geelong, Australia, made similar experiments in London with the same substance, he having produced from 5000 to 6000 pounds of ice per day with an engine of ten horse power.

In all machines using a chemical, the heat-carrying agent is maintained constantly in circuit, this agent not being expelled at a certain point as in air machines. The process of producing the cold is nearly the same in these as in the air machines, the vapor being compressed by the pumps into a condenser, and the heat due to the compression removed, liquefaction takes place; the liquid being then led into a system of pipes which are connected with the pump, and where the pressure is maintained below the boiling point of the liquid at the required temperature. The liquid will therefore boil or evaporate, abstracting at the same time from the surroundings, an amount of heat equal to that made latent by the evaporation, and the vapor formed will be taken up by the pump and again compressed, thus completing the circuit.

In all cases it is necessary that the whole apparatus shall be so tight as to exclude both air and water, as well as to prevent any leakage of the chemical; this, though not by any means an easy matter to accomplish, is of the utmost importance, since a leak *inward*, by admitting moist air or water, will, with some substances, ruin the entire apparatus; and a leak *outward*, not only wastes the chemical, but has in some cases been the cause of serious disasters to both life and property.

The principal points in favor of these machines is their small size compared with air machines. In a great part of the circuit the substance is in the liquid state, requiring tubes and vessels of very small dimensions.

In the air machines, the capacity of a certain volume of air for abstracting heat, depends entirely upon its *specific* heat; whilst in machines using liquefiable vapor the *latent* heat of the vapor is far more potent in this respect than the specific heat. And since the latent heat of most of the substances used is quite high, its utilization becomes of great advantage.

The substances generally used for the abstraction of heat are ammonia, sulphur di-oxide, methylic ether, chymogene, and others. Each of these substances has its advocates, and the superiority of one over another may depend much upon circumstances and the degree of cold to be produced. Yet, where the saving of space is important, many points are evidently in favor of ammonia.

There are two classes of ammonia machines in use, one using aqua ammonia, and the other the liquefied vapor, or anhydrous ammonia. In the former of these "absorption" machines, as they are called, the cold may be said to be produced directly by heat, without its previous

conversion into mechanical energy, the ability which water has of absorbing many times its volume of ammoniacal vapor being utilized to dispense with a large part of the machinery. So far, however, these machines have not proved as effective in the production of cold as those using mechanical energy.

To illustrate the advantage of anhydrous ammonia in point of space, a comparison of the relative latent heat of the substances named will be made, viz.:

Relative latent heat per equal weight,

Ammonia,	90
Sulphur Di-oxide,	26
Methylic Ether,	30
Chymogene,	17

and since the weight required to abstract a certain quantity of heat will be inversely as the latent heat of the substance, we see that the evaporation of *one* pound of ammonia will abstract as much heat as *three and a half* pounds of sulphur di-oxide, *three* pounds of ether, and *five and a quarter* pounds of chymogene.

The only reasonable objection that has been urged against the use of ammonia is the low temperature of its boiling point under atmospheric pressure, or inversely, the high pressure required to liquefy it at ordinary temperatures; this pressure need not, however, exceed 14 atmospheres absolute, or 206 pounds per square inch, which can be easily managed with proper apparatus.

But the boiling point of ammonia being low, becomes of great advantage where low temperatures are required; the pressure of its vapor being quite high, at a temperature where that of other substances is almost a vacuum, and this, taken in connection with the high latent heat of its vapor, makes the advantage gained by its use very apparent.

Pressure per square inch at 0° Fahr.,

Ammonia,	30	lbs. absolute.
Sulphur Di-oxide,	10	"
Methylic Ether,	20	"
Chymogene,	2	"

Assuming the volumes of the vapors to be inversely as the pressures, there would correspond to *one* volume of ammonia *three* of sulphur di-oxide, *one and a half* of methylic ether, and *fifteen* of chymogene, and combining this with the relation of the latent heat already given, it will be seen that where the formation of *one* volume of ammoniacal

vapor abstracts a given number of heat units, *ten and a half* volumes of sulphur di-oxide, *four and a half* of methylic ether, and *seventy-nine* of chymogene would be required to produce the same result. By these comparisons it will readily be seen that the whole apparatus and especially those parts through which the substance passes as vapor, will be of very small size, where ammonia is used, in comparison to that required when using any other substance; and this, which we have endeavored to explain at some length, we consider the most valuable point in its favor.

It is also non-poisonous as well as non-explosive, neither does it support combustion, that is to say, a burning taper introduced into the vapor is immediately extinguished—admirable points which give it precedence over substances like *ether* and *chymogene*, which are both liable to the objectionable features named. It is not known to produce any injurious effects upon either iron or steel, acting instead, when in a liquid state, as a good lubricant on those metals; mixed with water or moist air, it does not produce any deleterious action upon the apparatus, as is the case with sulphur di-oxide, where the admission of moisture is liable to cause a chemical change of the substance into sulphuric acid, or oil of vitriol, the injurious qualities of which are well known.

Ammonia being a strong alkali, non-saponifiable oils must be used where lubrication is required; these can be used indefinitely, as it is not known to have any action on them whatever.

Having so far endeavored to show the superiority of ammonia as a heat-carrying agent, we shall now give an outline of the apparatus required to produce a definite result.

Let it be required to abstract heat equivalent to the freezing of *ten tons of ice* in twenty hours, or a half a ton per hour, the water being at a temperature of 72° Fahr., the number of heat units to be abstracted per hour in reducing it to 32° and freezing it, would be 203,840, equal to 3397 heat units per minute. Supposing the temperature of the liquified ammonia, when in a condition to abstract heat from the water, to be at 0° Fahr., or 32° below the freezing point, one cubic foot of it, at that temperature, would require for its evaporation 36,295 heat units; but as the liquid when leaving the condenser is necessarily at a higher temperature, say 100°, a portion of it will be evaporated at the expense of the sensible heat, and subtracting this, it will be found that 30,762 heat units must be supplied by the water

for every cubic foot of ammonia evaporated. To abstract 3397 heat units would therefore require the evaporation of 191 cubic inches of liquid ammonia, corresponding to 95,616 cubic inches of vapor, which must be removed by the pump per minute.

Supposing the pump to make one hundred revolutions, if double-acting it would only need to have a capacity of 478 cubic inches, say 8 inches diameter by 10 inches stroke. Verifying what has been previously said about the small size of the apparatus.

The *initial* pressure corresponding to 0° Fahr. is about 30 pounds absolute, and the *final*, corresponding to 100° Fahr., about 200 pounds absolute, giving a ratio of compression of $6\frac{2}{3}$, and a mean effective pressure of 57 pounds per square inch, which for the above piston speed=167 feet per minute, and piston area=$50\frac{1}{4}$ square inches—would give a resistance of $14\frac{1}{2}$ horse power, which by adding 15 to 20 per cent. for prejudicial resistance will give the indicated horse power of the steam engine required to run it.

Additional power might be needed for the purpose of circulating water, etc., depending on the locality and the purpose for which the cold was intended; but in any case the available mechanical energy being known, the amount of cold it can produce may be easily calculated, and the results, as obtained in practice, sustain the truth, not only of the possibility, but also of the magnitude of the conversion of mechanical energy into cold.

Electric Illumination by Reflection.—D. V. Partz exhibited a plan of a new mode of electric lighting, at the French Electric Exposition. The light was placed in chambers underneath the street, and reflected through hollow cylinders, enamelled on the inside, so as to produce an inverted cone of rays, which strike a reflector placed at a height of 40 or 50 metres above the street. Among the advantages which are claimed by the inventor are: The employment of powerful electric foci, thus avoiding the loss which results from the division of the current; the equal diffusion of the light and the avoidance of the dazzling glare; the diminution of the loss of light which results from the employment of translucent globes; the readiness of access for regulation and surveillance; and the illumination of thick mists, which can be penetrated with difficulty by other methods.—*La Lumière Electrique*, Aug. 5, 1882.

ON THE APPLICATION OF THE PRINCIPLE OF VIRTUAL VELOCITIES TO THE DETERMINATION OF THE DEFLECTION AND STRESSES OF FRAMES.

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I. INTRODUCTION.

The calculation of the deflection of a truss or girder is a subject which sometimes occupies the attention of the engineer, yet in regard to which some uncertainty seems to prevail. The deflection is of importance from several points of view, and it is sometimes considered an index of the strength of the structure; so that we sometimes find it specified that the deflection shall not exceed a certain quantity under a given load, to determine which systematic tests are made on the completion of the structure. There is no doubt, however, that the importance of the deflection as an index of strength has often been overestimated, and for the following reason: That the deflection consists of two parts, which must be carefully distinguished; first, that due to the changes of length of the bars composing the frame, on account of the stresses produced in them by the applied loads; and, second, that due to inaccuracies of workmanship,—to the fact that the parts do not exactly fit, that bolts and rivets are not of exactly the right size, etc.—so that the parts all come gradually to their permanent bearings, producing a certain deflection. The first sort of deflection may be called the *elastic*, the second the *non-elastic*: the first may be approximately calculated; the second cannot be: the first should be temporary, disappearing when the loads are removed; the second is permanent: the first is to a certain extent an index of the strength of the structure; the second is not. When a new bridge is loaded for the first time it deflects; but even if we measure the deflection, we have no means of knowing how much is elastic and how much non-elastic, consequently we cannot from this alone judge of the strength of the structure. If, as in the case of long spans and pin connections, we can be reasonably certain that the dead load alone is sufficient to bring all the parts to their permanent bearings, the measurement of the deflection would

have a certain value; or if a bridge has been in use long enough to render it certain that the maximum non-elastic deflection has been reached, the same is true; for in these cases the measured will be the elastic deflection. Yet, even here, a single measurement would have no value. By repeated applications of the load, however, we can observe whether the elastic deflection is gradually increasing, and so gain some insight into the condition of the structure; for if no increase be observed, we may know that no bar is strained beyond the elastic limit. Yet, even here, again, it would be just as easy to calculate the stresses in each bar, and so dispense with the measurement, except in cases where, for some reason, an exact calculation is impossible or uncertain. Again, in order to calculate the deflection of a frame, it is necessary to know the modulus of elasticity of each bar, regarding the value of which there is not often certainty; hence, if the calculated and observed deflections do not agree, no definite conclusions follow. It would no doubt be an advantage to confine the non-elastic deflection within certain limits, but how this can be done in any other way than by exercising care in the construction, it is difficult to see. It would seem, then, that the only value which a measurement of deflection has, is that by repeating the measurement we may judge whether any bar is strained beyond the elastic limit; and in view of our large factors of safety, which do not allow the elastic limit to be approached in good constructions, this value is not great.

But there is another point of view from which the deflection is of greater interest. There are some structures in which the stresses themselves depend on the deflections—structures which may be called "statically undetermined;" and although they do not occur often in the ordinary practice of the engineer, a study of their properties, and of the methods of calculating them, is of value and interest. The usual methods employed involve assumptions which are more or less removed from the truth, and the error committed in the calculation is of uncertain amount. Some of these structures, however, may be solved with exactness by means of a method which has been known for a number of years, and the application of which, though sometimes tedious, is not difficult. It is a method of successive approximation; and as its details may not be familiar to some readers of the JOURNAL, it may be of interest to give them in the following pages. The first application of the method is due, I believe, to Lamé; it was subsequently treated more fully by Maxwell and Jenkin in England; and

fully developed in recent years in Germany, in all its applications, by Mohr and Winkler. The object of this paper is to attempt to present an outline of the method and of its principal applications. Before doing so, however, it may not be out of place to recapitulate briefly a few facts regarding frames in general, and the conditions under which they are statically determined. We may do this the more briefly because of the appearance, since the present article was commenced, of an article by William Cain, C. E., in *Van Nostrand's Magazine* for October, in which some of these points are referred to.

A frame may be defined as an assemblage of bars united at their ends by hinges, and supported at one or more points. For the present let us consider the case of two points of support only. If such a frame is acted upon by forces applied at the joints, each rod will be subjected to longitudinal stress, and to find the stress in each piece is the problem to be solved. This problem presents two distinct parts: first, the determination of the outer forces, or reactions, by which the applied forces are held in equilibrium; and, second, the determination of the inner forces, or stresses in the bars; and in order to solve the second part of the problem, we must beforehand have solved the first. For the solution of either or both of these parts of the problem the laws of statics may not suffice, in which case the frame may be called statically undetermined as regards outer or inner forces, and in which, in order to effect a solution, it is necessary to resort to considerations based on the elasticity of the materials dealt with—generally to a determination of deflection.

Let us see now, first, under what conditions the *outer forces* may be determined on statical principles alone. The outer forces consist of

Fig. 1

the applied loads, which are known, and the reactions, which are unknown. Confining ourselves to the ordinary case of a frame of any shape, supported at two points, all of the bars lying in a plane, in which plane also the loads and reactions act, we resolve the two reactions R_1 and R_2 into their horizontal and vertical components, H_1 and H_2, and V_1 and V_2. Assume any system of rectangular axes Ox,

Oy, in the plane of the frame. In order to determine the reactions completely, eight unknown quantities must be found, namely, for each reaction its two components and the two co-ordinates of its point of application. To find these quantities eight equations are necessary. The surfaces of support being always given, afford two equations, between x_1, y_1, and x_2, y_2. For simplicity we may therefore consider that we have six unknown quantities, H_1, H_2, V_1, V_2, x_1, x_2, for which we require six equations. Statics furnishes us with but three—the equations of equilibrium of forces in a plane, expressing the fact that the loads are balanced by the reactions. Three additional equations or conditions are therefore necessary, if the frame is to be statically determined as regards the outer forces. The conditions usually given will be referred to again, in connection with the calculation of the outer forces in some of the most common cases. It is sufficient here to refer to the fact, that, of the three, one, and sometimes two or three, are derived from a consideration of the deflection of some point in the frame in some particular direction.

Passing now to the inner forces, let us see under what conditions the stresses in all the bars of the frame may be found from statical principles alone, the outer forces being supposed determined. At each joint of the frame the stresses in the bars meeting at that joint are the quantities to be determined; and the only statical conditions that we have, from which to determine them, are those expressing the fact that they are in equilibrium with the outer forces acting at the joint. The conditions of equilibrium for forces acting at a point are two in number; hence for each joint of the frame we can write two statical equations involving the unknown quantities; and if there are m joints in all, we have $2m$ statical equations. These $2m$ equations express the fact that each and every joint is in equilibrium, therefore that the entire frame is in equilibrium; hence they include the three conditions of equilibrium of the outward forces themselves, so that there remain $2m-3$ independent equations for the determination of the stresses in the bars, which we suppose n in number. To express this in another way, the $2m$ equations express the fact that the outer forces are balanced; we cannot, then, assume all of our outer forces *ad libitum*, because we must assume them so that they will satisfy the three conditions of equilibrium of forces in a plane; but we can assume all but three components, which we leave as unknown quantities, and we thus have $2m$ equations to determine the $n+3$ unknown quantities. It is clear, then,

that if the inner forces can be statically determined we must have the condition fulfilled:

$$2m=n+3, \qquad (1)$$

and this equation must be fulfilled not only for the entire frame, but for any part which may be cut off from the rest, the stresses in the bars cut being considered outer forces. Equation (1), demonstrated above on mechanical principles, has been deduced by Maxwell and others geometrically, by considering the conditions under which any one bar may change its length without involving a change of length of the others.

It is not necessary to give many examples of the application of this condition. A rectangle with one diagonal, for instance, is statically determined, but if the second diagonal be added, it becomes statically undetermined. It may be remarked, however, that all bridge trusses which have more than one system of bracing are statically undetermined; and as such are the prevailing trusses used in this country, it may be well to show in a few words why this is so. We shall find, for instance, in Fig. 2, leaving out the two counter ties running from the point *j*,

$$2m=36\,;\ n+3=38:$$

and in Fig. 3,

$$2m=36\,;\ n+3=37.$$

In each of these cases, therefore, the number of unknown quantities

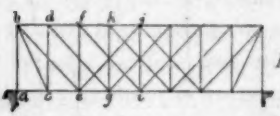


Fig. 2

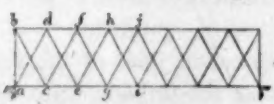


Fig. 3

is greater than the number of equations. so that additional equations are needed in order to solve the problem.

If the number of equations should be greater than the number of unknown quantities, the system would be unstable, and would change its shape as the load changed; such is the case in flexible suspension bridges. It is easy to see why the two trusses considered above, are statically undetermined. They are generally solved by being resolved into two simple trusses; for example, in Fig. 2, into *a*, *b*, *c*, *d*, *g*, etc., and *a*, *b*, *e*, *f*, *i*, etc.; and in Fig. 3, into *a*, *b*, *c*, *f*, *g*, etc., and *a*, *d*, *e*, *h*, *i*, etc. This method of calculation involves the supposition that in the first system (Fig. 2), the chord pieces, *bd*, *dh*, *eg*, etc. remain straight, making angles with each other at the joints *c*, *d*, *g*, *h*; while

in the second system the chord pieces, *ae*, *bf*, *ei*, etc. are supposed to remain straight, making angles with each other at *e*, *f*, etc. These two suppositions being in direct opposition, it is easily seen that the ordinary method of calculation is not exact, the systems being really statically undetermined. It can be shown, however, as it is important to remark, that the error made in calculating these trusses in the ordinary way is small enough to be neglected.

There will be occasion to refer briefly, on a subsequent page, to the arguments for and against systems which are statically undetermined. The weight of opinion among those best acquainted with the subject, seems to be that they are not to be recommended, except in cases like those just examined, where the error of an ordinary calculation is very small, and where practical advantages are gained by their use. Nevertheless, they are sometimes applied from choice, and sometimes almost from necessity. The simple method which will be explained, and by means of which they may be calculated, will commend itself to all.

Before proceeding, we may remark that it is easy to discover the conditions under which frames supported at one point (or rather one surface or support), or at more than two, are statically determined as regards the outer forces. Thus a frame supported at one point has only one reaction, and to determine that reaction completely, four quantities must be known, viz.: its two components, and the two co-

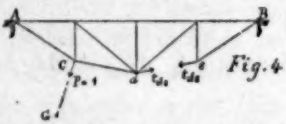


Fig. 4

ordinates of its point of application. Three equations being given by statics, one other condition is necessary, and this may be given in various ways. A frame supported at n places, like a continuous girder of $n-1$ spans, has n reactions, to determine which, $4n$ quantities are necessary. If the point of application of each reaction is given, and if all but one are vertical, we have $3n-1$ conditions; but it is necessary to have $4n-3$ conditions hence $n-2$ additional conditions are necessary, and these are given, in the ordinary method of treatment, by the theorem of three moments, which gives exactly $n-2$ elastic conditions.

II. Elastic Deflection of Frames.

Consider the bridge truss represented in Fig. 4, supported at A and

B, and let it be required to find the elastic deflection of any joint C, in any direction, $C\,G$, the loading being given. This deflection is due solely to the changes of length of the bars composing the frame, and if we can determine the effect of the change of length of each bar separately, our problem will be solved. This is done in the following manner: suppose a force P, equal to unity to be applied at C, in the direction $C\,G$, and to be the only load on the truss; and let the stresses produced by this force in the bars of the frame, be represented by t_{de}, etc. These stresses may be determined statically, in this case, as the system satisfies equation (1). Suppose, for a moment, all the bars except de to be perfectly rigid, not changing their lengths at all, and let de be removed, and the two forces, t_{de} be applied as represented at d and e. We have, then, a frame acted upon by the reactions at A and B, and by the following other forces: unity at C, t_{de} at d, and t_{de} at e, in the directions indicated in the figure. By the principle of virtual velocities, for a very small deformation, the work done by these forces must equal zero; or, as the reactions do no work, that done by P must equal that *done against* t_{de}: in other words, if P produce tension in de, as in the figure, the length de is increased, and the work done by P must equal the work done in extending the bar de. If we call Δ_{de} the deflection of C along $C\,G$, and if we suppose the load P applied gradually, so as to cause no vibration, the average value of the load at C is $\frac{1}{2}\,P$, and the work done is $\frac{1}{2}\,P\Delta_{de}$; or, as $P=1$, the work is $\frac{1}{2}\,\Delta_{de}$. The average value of the stress in de is $\frac{1}{2}\,t_{de}$, and the work done is $\frac{1}{2}\,t_{de}\,\Delta l_{de}$, if Δl_{de} is the change of length of de. Hence

$$\tfrac{1}{2}\,\Delta_{de}=\tfrac{1}{2}\,t_{de}\,\Delta l_{de},\text{ or }\Delta_{de}=t_{de}\,\Delta l_{de} \qquad (2)$$

Now it is clear that Δ_{de} depends only on the change of length Δl_{de} of the bar de. If that change of length is, say, one inch, then it matters not how it is produced,—whether by loads, temperature, or any other cause,—the deflection of the point C will be the same. Hence, if we represent by Δl_{de} the real change of length of de, which is caused by any forces, or in any way whatever, Δ_{de} will still be given by the same equation. Consequently, if we wish to find for given loading, the deflection of C along $C\,G$, we can find that part of it which is due to the bar de from equation (2), which becomes $\Delta_{de}=t_{de}\left(\frac{sl}{FE}\right)_{de}$, s being the stress produced by the given loads, l the length, F the section, and E

the modulus of elasticity, all referring to *de*. One point must be carefully noticed as regards this equation, namely, that if Δ_{de} is to be positive, that is, if C is to move toward G, the change of length *de*, must be in the same direction as that due to t_{de}. If t_{de} is a tension, while the given loads cause compression, Δ_{de} will be negative. It is only necessary, in calculating t_{de} and s_{de}, to assume tension as positive, and compression as negative, and if all the signs are carefully observed, the result will be correct. In order, then, to find the total deflection of C, due to the changes of length of all the bars of the frame, we must only calculate the value of the expression in the above equation, for all the bars, or we have

$$\Delta = \Sigma t . \frac{sl}{FE}. \qquad (3)$$

This equation is perfectly general in its application, giving us with almost absolute accuracy, the *elastic* deflection in any direction of any point of a *framed* structure, truss, pier, arch, suspension system, etc. We say with *almost* absolute accuracy, simply because as the frame changes its shape the stresses in the bars become slightly different, and this change of stress is of course neglected. In order to find the absolute elastic deflection of any point, it is only necessary to find its deflections in two directions at right angles to each other. Their resultant gives the true deflection.

The equation above involves the section and modulus of elasticity of every bar in the frame, and, unless these are known, the deflection cannot be calculated. Hence we see why in cases when the equation is to be used as a means of calculating the stresses in frames, inasmuch as here the stresses and sections of the bars are the very quantities to be determined, a method of successive approximation must be resorted to, by first calculating the sections by some approximate method, and afterwards correcting them.

The fraction $\frac{s}{F}$ is the stress per square unit caused by the *given load*, but is evidently not constant.

One other source of error in the equation must be noticed, namely, that it does not take account of the shortening of length due to the bending of compressed pieces. This error cannot be corrected without introducing considerable complication, and perhaps not at all, but it is probably not very large in ordinary cases.

The use of the equation may be illustrated by some examples. Let us take first the frame shown in Fig. 5, loaded at the point A, with a force P, and let it be required to find the vertical deflection of this point. Suppose first the bar BC to be inelastic, or absent, the horizontal

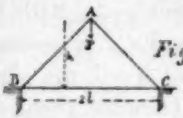


Fig. 5

thrust at B and C being supplied by unyielding abutments. Then we have

$$t_{ba}=t_{ca}=\tfrac{1}{2}\,\frac{\sqrt{l^2+h^2}}{h},$$

and

$$s_{ba}=s_{ca}=\frac{P\sqrt{l^2+h^2}}{2h},$$

hence

$$\Delta=2\,\frac{P.(l^2+h^2)^{\frac{3}{2}}}{4h^2F_{ab}E_{ab}}=\frac{P.(l^2+h^2)^{\frac{3}{2}}}{2h^2F_{ab}E_{ab}}.$$

This is the same expression, which was found in a more roundabout way, by Prof. DuBois, on page 124 of this JOURNAL, for February, 1882.

If we suppose BC to be elastic, we have

$$\Delta=\frac{P\,(l^2+h^2)^{\frac{3}{2}}}{2h^2F_{ab}E_{ab}}+\frac{Pl^3}{2h^2F_{bc}E_{bc}},\text{ or, if }E_{ab}=E_{bc}=E,$$

$$\Delta=\frac{P}{2h^2E}\left[\frac{(l^2+h^2)^{\frac{3}{2}}}{F_{ab}}+\frac{l^3}{F_{bc}}\right].$$

In applying the method to bridge trusses with many pieces, it is best to arrange the result in tabular form. As an example, take one truss of the Broadway bridge, in Boston, as shown in Fig. 6, with

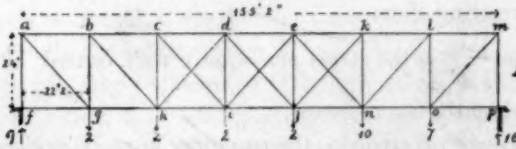


Fig. 6

the given loading. The span is 155 feet 2 inches, and the sections and lengths of the bars are given in the following table. Let it be required to find the vertical deflection of the point h. We first fill out the first four columns of the table, from the known data, then find

Bar.	Length l Inches	Section F Sq. ins.	Modulus of Elasticity. E. Tons per sq. inch.	t. Tons.	s Tons.	$\frac{l}{E}$	$\frac{ts}{F}$	$\Sigma\frac{tsl}{EF}$
ab	266	36·0	12,500	−0·66	− 8·316	0·02128	+0·1525	
bc	"	38·15	"	−1·32	−14·784	"	+0·5115	
cd	"	59·56	"	−1·056	−19·404	"	+0·3440	
de	"	59·56	"	−0·792	−22·176	"	+0·2949	
ek	"	59·56	"	−0·528	−23·100	"	+0·2048	
kl	"	38·15	"	−0·528	−23·100	"	+0·3197	
lm	"	36·0	"	−0·264	−14·784	"	+0·1084	
fg	"	12·25	"	0	0	"	+0	0·0083
gh	"	15·75	"	+0·66	+ 8·316	"	+0·3485	
hl	"	27·00	"	+1·32	+14·784	"	+0·7228	
ij	"	28·70	"	+1·056	+19·404	"	+0·7140	
jn	"	27·00	"	+0·792	+22·176	"	+0·6505	
no	"	15·75	"	+0·264	+14·784	"	+0·2478	
op	"	12·25	"	0	0	"	+0	
af	288	30·00	"	−0·71	− 9·00	0·02304	+0·213	
bg	"	21·00	"	−0.71	− 7·00	"	+0·2367	
ch	"	13·80	"	+0·29	− 5·00	"	−0·1051	
di	"	10·80	"	+0·29	− 3·00	"	−0·0806	0·012
ej	"	10·80	"	+0·29	− 1·00	"	−0·0269	
kn	"	13·80	"	0	0	"	+0	
lo	"	21·00	"	−0·29	− 9·00	"	+0·1243	
mp	"	30·00	"	−0·29	−16·00	"	+0·1547	
ag	392	23·75	"	+0·966	+12·24	0·03136	+0·498	
bh	"	16·88	"	+0·966	+ 9·52	"	+0·5448	
ci	"	10·12	"	−0·394	+ 6·80	"	−0·2647	
ah	"	1·23	"	0	0	"	+0	
dj	"	4·38	"	−0·394	+ 4·08	"	−0·367	0·0195
ei	"	4·38	"	0	0	"	+0	
en	"	1·23	"	−0·394	+ 1·36	"	−0·4356	
kj	"	10·12	"	0	0	"	+0	
nl	"	16·88	"	+0·394	+12·25	"	+0,286	
om	"	23·75	"	+0·394	+21·76	"	+0·361	
						$\Delta = \Sigma\frac{tsl}{EF} =$		0·1297″

the stresses t, due to a vertical load unity in h, and finally the stresses s, due to the given loading. In calculating the stresses t, those bars are to be considered as in action which are really in action *under the given loading*, although they would not be the ones really acting if a load were to act in h alone. Assuming the modulus of elasticity to be 25,000,000 pounds per square inch, the resulting value of the deflection of the point h is a little over one-eighth of an inch. It is interesting to observe the relative effects of the chords and the web.

Leaving out the web members, the deflection is found to be 0·0983 inch, or about one-tenth of an inch. The relative effect of chords and web is as ·0983 to ·0314, or about as 3 to 1. It is therefore hardly correct, judging from the case, to neglect the influence of the web on the deflection, as is done, for instance, in most cases, in the treatment of continuous girders and framed arches. Some method seems to be called for by which each bar can be considered, and such a method is that afforded by the application of the principles which have been explained.

Having shown how to find the elastic deflection of any point in a frame which is statically determined, we may proceed to cases where a determination of deflection is involved, or those where the frame is statically undetermined regarding either the outer or the inner forces. Let us consider first the case where there is difficulty regarding the outer forces, or reactions. We have already seen that we must have three conditions involving the unknown quantities, in order to be able to find the reactions completely. If we support the truss in such a way that the points of application of the reactions are known, we have two of the necessary conditions (confining ourselves, as before, to a frame lying in the plane of the outer forces, and supported at two points), or if we introduce a hinge at any point in the frame, so that a section through this hinge divides the frame completely, without cutting any other bars, then the condition that the moment of the outer forces about the hinge is zero, is one of the conditions sought. By putting in three hinges, then, we supply three conditions, and are enabled to solve the problem by the use of statics alone, without the aid of the theory of elasticity.

The principal cases of frames supported at two points are the simple truss and the various forms of arches. In the simple truss we have the two points of application of the reactions, and the condition $H_2 \lessgtr fV_2$, f being the co-efficient of friction, and the end where R_2 acts

being free to move horizontally, while the other end is fixed. In the arch hinged at crown and springing, also, we have the three conditions given; these two cases need not therefore be dwelt upon, and there remain only the cases of arches with fewer than three hinges.

We confine our attention to the effect of the elastic deflection.

III. The Arch Hinged at Springing.

We consider under this head the case of the arch hinged at each springing point. Only one additional condition is required in order

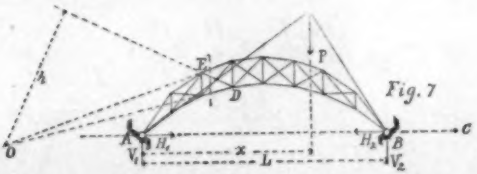


Fig. 7

to find the reactions, and this condition is that the change of the span under loads is either zero or a known quantity. This change of span is the horizontal deflection of the point B. Hence a solution of the question involves a consideration of the principles just discussed. Confining ourselves to the case where AB is horizontal, and the loads acting on the arch vertical, as is usually the case, we see at once that $H_1=H_2=H$, and that the vertical reactions are the same as for a simple girder, or distributed according to the law of the lever. Thus for a load P, at a distance x from A, $V_1=P\frac{L-x}{L}$. $V_2=P\frac{x}{L}$. The only unknown quantity is H, which may now be easily found. Let us suppose first that the arch is supported by vertical reactions, or that $H=o$, and let it be loaded in any way desired. The point A, being fixed, B will move outward a distance $\Delta L_v=\Sigma t\frac{s_v l}{FE}$, according to equation (3). In this equation, E is the modulus of elasticity, F the cross-section, and l the length of any bar; s_v the stress produced in it by the given vertical loads, and t the stress produced in it by a horizontal force unity acting in B, and *outwards* towards C (the corresponding reaction acting outwards in A). This is clear from what has preceded. Now if the span is to remain constant, the horizontal thrust H, acting in B, towards A, must be sufficient to bring the point B back to its original position. Suppose H to be the only force acting, and let the

stresses which it causes in the bars be denoted by s_h. Then the horizontal deflection of B towards A, is

$$\Delta L_h = \Sigma - t\frac{s_h l}{FE},$$

because we must put instead of t the stresses produced by a load unity in B acting inward, or $-t$. We also have $s_h = -tH$, hence

$$\Delta L_h = H\Sigma\frac{t^2 l}{FE}.$$

Placing ΔL_v and ΔL_h equal to each other, and calling E constant, we have

$$\frac{1}{E}\Sigma\frac{t.s_v.l}{F} = \frac{H}{E}\Sigma\frac{t^2 l}{F},$$

or

$$H = \frac{\Sigma\frac{t.s_v.l}{F}}{\Sigma\frac{t^2 l}{F}} \tag{4}$$

This equation applies when the abutments are immovable. If A and B are connected by a rod of section F_1, and modulus of elasticity E_1, its length being L, then its change of length, which is the deflection of B outward, is known, and given by the equation

$$\Delta L = \frac{HL}{F_1 E_1} \tag{5}$$

We have, then, in this case,

$$\Delta L_v = \Delta L_h + \Delta L,$$

or

$$\Sigma\frac{t.s_v l}{FE} = H\Sigma\frac{t^2 l}{FE} + \frac{HL}{F_1 E_1} \tag{6}$$

whence

$$H = \frac{\Sigma\frac{t.s_v l}{FE}}{\Sigma\frac{t^2 l}{FE} + \frac{L}{F_1 E_1}} \tag{7}$$

and, if E is constant,

$$H = \frac{\Sigma\frac{t\,s_v l}{F}}{\Sigma\frac{t^2 l}{F} + \frac{L}{F_1}} \tag{8}$$

H being found, the real stress in any bar is

$$S = s_v - t\,H \tag{9}$$

These simple equations suffice for the solution of this case. The tabular form is the best for computation, and the signs of the stresses must be carefully observed. A discussion of the best methods of finding the maximum stress in each bar of the frame does not belong here.

It is interesting, however, to note one transformation of equation (4). That equation may be written

$$\Sigma \frac{tl}{F} [s_v - tH] = o \tag{10}$$

or, according to equation (9)

$$\Sigma \frac{tlS}{F} = \Sigma t.\Delta l = o \tag{11}$$

S being the real stress in any bar, and Δl its change of length. But $S = \frac{M}{h}$, M being the moment about the origin of moments for the bar considered, and h the lever arm of that bar. Also, $t = \frac{z}{h}$, z being the ordinate above AB of the origin of movements. Inserting these values in equation (11) we have

$$\Sigma \frac{Mzl}{Fh^2} = o \tag{12}$$

If we neglect entirely the influence of the web members, the summation extends only over the chord pieces, and z is the ordinate of a joint, while h is the distance between the chords. At any point, the moment of inertia of the chord sections about an axis midway between them is approximately

$$I = 2F.\frac{h^2}{4} = \tfrac{1}{2} Fh^2.$$

Hence we have

$$\Sigma \frac{Mzl}{I} = o. \tag{13}$$

The analogy of this equation to that which is often given for solid arches, namely $\int \frac{M}{I} z\, ds = o$, is apparent. It must not be forgotten, however, that it is not accurate.

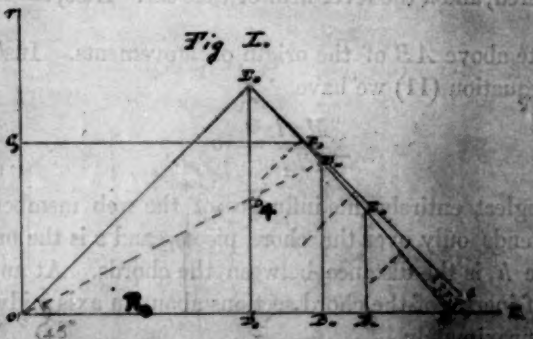
(To be continued.)

CONE PULLEYS.

By H. W. SPANGLER,
Assistant Engineer U. S. Navy.

The writer, in attempting to solve the problems arising in designing a pair of cone pulleys, with open belts, tried to use some one of the methods already known, but found that these methods were too complicated, too inaccurate, or not of sufficient range to cover all cases liable to arise.

Two of these methods are intended to solve the problems completely. One, by Prof. J. P. Klein, of Lehigh University, was published in a series of articles in the *American Machinist*, Vol. 2. The tables there given will give good results if used correctly; but unfortunately, five out of seven cases, which are solved by the computer himself, give incorrect results. Evidently the tables are not just what is required.



The other method referred to is one published by [illegible]. Nystrom, in the first volume of Mechanics. This method is not complete, as it requires that the diameter of the pulley, which is to be [illegible] each shaft, shall be known, and it is also a long method of arriving at a simple result.

The application of the method arrived at by the writer is given first and the proof afterwards.

The following notation is used: a, Fig. 2, is the perpendicular distance between the shafts. R and r are the radii of any two pulleys connected by the belt, R being the larger. R_0 is the value of R when $R=r$.

First calculate the value of R_o, having any two corresponding radii R and r given, from the formula

$$R_o = \frac{R+r}{2} + \cdot 15915 \frac{(R-r)^2}{a}.$$

Having assumed or calculated this value, draw two lines, $O\,R$ and $O\,r$, at right angles to each other, Fig. 1. Lay off $O\,D_o = R_o$ along $O\,R$ and draw $D_o\,E_o$ parallel to $O\,r$ and equal to R_o. Draw $O\,E_o$.

Calculate the distance

$$O\,B = \sqrt{6\cdot 2832 \times a \times R_o + 2\cdot 4674 \times a^2} - 1\cdot 5708 \times a,$$

and mark the point B. Draw, through E_o, the line $A\,E_o$ at right angles to $O\,E_o$, and through B draw $B\,A$ parallel to $O\,E_o$. Divide $A\,E_o$ into any number of equal parts and $A\,B$ into the same number. Through the divisions of $A\,E_o$ draw lines parallel to $O\,E_o$ and join the divisions of $A\,B$ to E_o. Where these two sets of lines meet are points in the arc of a parabola passing through B and E_o and having $O\,E_o$ for an axis. If the divisions of $E_o\,A$ are not over an inch apart, the diagram being drawn full size, the points found can be joined by a broken line without giving rise to an appreciable error.

Having drawn the curve, the radii of any corresponding pulleys can be measured from it as follows. Having given one radius as R_2, greater than R_o, lay it off along $O\,R$ to B_2. Erect the perpendicular

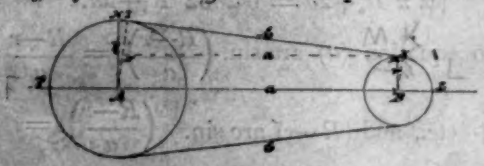


Fig. 2.

$B_4\,E_4$ and this line is the radius r_2 corresponding to R_2. If a radius r_3 less than R_o is given, draw $O\,C_3$ equal to r_3, and through C_3 draw $E_3\,C_3$ parallel to $O\,R$. $E_3\,C_3$ is the radius, R_3 corresponding to r_3.

If it is required that two pulleys, R_4 and r_4, shall have certain relative diameters or radii, divide $D_o\,E_o$ in the ratio of the radii so that $\frac{D_o\,E_o}{D_o\,D_4} = \frac{R_4}{r_4}$. Draw $D_4\,O$ and $r_4 = E_4\,B_4$ and $R_4 = B_4\,O$.

The length of the belt can be found from the formula

$$6\cdot 2832\,R_o + 2a.$$

Proof.

Let A and B, Fig. 2, be any two corresponding pulleys, whose radii are R and r, connected by the open belt $C\,C$. Suppose the

distance between the centres of the pulleys to be a. The half-length of the belt is $L\,K\,I\,H\,F$.

$$L\,K = r\left\{\frac{\pi}{2} - \text{angle } M\,B\,K\right\}$$

$$K\,I = \sqrt{a^2-(R-r)^2}$$

$$I\,H\,F = R\left\{\frac{\pi}{2} + \text{angle } I\,A\,H\right\},$$

or the half-length of the belt is $r\left\{\frac{\pi}{2} - \text{angle } M\,B\,K\right\} + \sqrt{a^2-(R-r)^2}$ $+ R\left\{\frac{\pi}{2} + \text{angle } I\,A\,H\right\}$. The angle $M\,B\,K$ = angle $I\,A\,H$ = angle $I\,K\,N$ = arc sin. $\left(\frac{R-r}{a}\right)$, and the half-length of the belt is

$$(R+r)\frac{\pi}{2} + (R-r) \text{ arc sin.}\left(\frac{R-r}{a}\right) + \sqrt{a^2-(R-r)^2} \qquad (a.)$$

If, when $R=r$, we call the radius R_o, we leave for the half-length of the belt

$$R_o\,\pi + a$$

and the length of the belt is

$$2\,\pi\,R_o + 2a = 6{\cdot}2832\;R_o + 2a.$$

Going back to equation (a) arc sin. $\left(\frac{R-r}{a}\right) = \frac{R-r}{a} + \frac{(R-r)^3}{6a^3}$ $+ 3\,\frac{(R-r)^5}{40a^5}$ + etc., and $(R-r)$ arc sin. $\left(\frac{R-r}{a}\right) =$

$$\frac{(R-r)^2}{a} + \frac{(R-r)^4}{6a^3} + \frac{3(R-r)^6}{40a^5} + \text{etc.}$$

$$\sqrt{a^2-(R-r)^2} = a - \frac{(R-r)^2}{2a} - \frac{(R-r)^4}{8a^3} - \frac{(R-r)^6}{16a^5} - \text{etc.},$$

and the half-length of the belt or $\pi\,R_o + a =$

$$(R+r)\frac{\pi}{2} + \frac{(R-r)^2}{a} + \frac{(R-r)^4}{6a^3} + 3\,\frac{(R-r)^6}{40a^5} + \text{etc.} + a - \frac{(R-r)^2}{2a}$$

$$- \frac{(R-r)^4}{8a^3} - \frac{(R-r)^6}{16a^5} - \text{etc.} =$$

$$a + (R+r)\,\frac{\pi}{2} + \frac{(R-r)^2}{2a} + \frac{(R-r)^4}{24a^3} + \frac{(R-r)^6}{80a^5} + \text{etc.}$$

The terms $\frac{(R-r)^4}{24a^3} + \frac{(R-r)^6}{80a^5}$ + etc. can be omitted, because for all practical values of R, r, and a, their sum would be very small, and we have

$$\pi R_o + a = a + \frac{(R+r)\pi}{2} + \frac{(R-r)^2}{2a},$$

or

$$\pi R_o = \frac{(R+r)\pi}{2} + \frac{(R-r)^2}{2a}.$$

From this we get the equation

$$R_o = \frac{R+r}{2} + \frac{(R-r)^2}{2\pi a} = \frac{R+r}{2} + \cdot 15915\,\frac{(R-r)^2}{a}.$$

If, as in Fig. 1, we take two lines at right angles to each other, and lay off on these lines distances equal to R as abscissæ and r as ordinates, the curve formed will be the curve whose equation is

$$\pi R_o = (R+r)\,\frac{\pi}{2} + \frac{(R-r)^2}{2a}. \qquad (b.)$$

This is the equation of a parabola whose principal axis is a line passing through O, Fig. 1, at an angle of 45° to $O\,R$ and $O\,r$, and whose vertex is at the point where $R=r=R_o$. In order to construct the curve one other point is required, and this can be found by putting $r=o$ and we have

$$\pi R_o = R\,\frac{\pi}{2} + \frac{R^2}{2a}.$$

Solving this equation for R gives

$$R = O\,B \text{ (Fig. 1.)} = \sqrt{2\pi a R_o + \frac{\pi^2 a^2}{4}} - \frac{\pi a}{2},$$

or

$$O\,B = \sqrt{6{\cdot}2832 \times a \times R_o + 2{\cdot}4674 \times a^2} - 1{\cdot}5708 \times a.$$

Having found this point, the parabola can be constructed as shown before, and the co-ordinates of any point on it are the radii of corresponding steps of two cone pulleys.

It may not be readily seen that the equation (b) is the equation of a parabola, but if for R we put $(x+R_o)$ and for r we put $(y+R_o)$, the shape of the curve is not changed but the axes are moved parallel to themselves to the point E_o, and the equation (b) becomes

$$\pi R_o = (x + y + 2\,R_o)\,\frac{\pi}{2} + \frac{(x-y)^2}{2a},$$

or $$2\pi R_o = \pi x + \pi y + 2 R_o \pi + \frac{(x-y)^2}{a},$$

or $$\frac{(x-y)^2}{a\pi} + x + y = O. \qquad (c.)$$

If in equation (*c*) we put for x the value $\left\{\frac{x_1}{\sqrt{2}} + \frac{y_1}{\sqrt{2}}\right\}$, and for y the value $\left\{\frac{x_1}{\sqrt{2}} - \frac{y_1}{\sqrt{2}}\right\}$, we change the direction of both axes 45°, but do not change the curve, which is still the same curve as given by equation (*b*).

Making these substitutions in (*c*) we have

$$\frac{(y_1\sqrt{2})^2}{\pi a} + x_1\sqrt{2} = O,$$

or $$y_1^2 = -\frac{a\pi}{\sqrt{2}} x_1,$$

which is the well-known equation of a parabola having one of the axes of co-ordinates for a diameter, and having the vertex at the origin of co-ordinates; and the curve given by equation (*b*) must be a parabola whose axis is at 45° to $o R$ and whose vertex is at $R = r = R_o$.—*University of Pennsylvania, Philadelphia*, Dec. 14, 1882.

Argentine.—The product which is known in commerce under the name of argentine, and which is employed for printing upon cloths and paper, is a tin moss or sponge, obtained from the precipitation of a solution of chloride of tin by zinc. The solution, strongly acidulated at first, must be diluted until it contains 60 litres of water (15·85 gallons) for 150 grammes of the tin salt. The sponge must be collected with care and without compression in a sieve, then washed in water and dried by heat. It may then be finally brayed with water in a mortar, passed through a hair sieve and mixed with starch paste for printing. The small quantity of the sponge which remains upon the sieve is dissolved in a mixture of equal parts of chlorhydric acid and water and added to the tin solution. The same water may be used from ten to thirteen times. The chloride of zinc in solution may be evaporated and used for soldering or for cleansing objects which are to be tinned. The gray tin powder can be economically employed for tinning all metals but lead.—*Chron. Industr.*, Oct. 19, 1882. C.

DUST EXPLOSIONS IN BREWERIES.

By C. JOHN HEXAMER.

[A paper read at the stated meeting of the Franklin Institute held January 17, 1882.]

I do not, in this short paper, intend to give a detailed treatise concerning malt dust explosions, as in the September number of the JOURNAL, a reprint of Prof. Tobin's address delivered before the "Fire Underwriters' Association of the Northwest," on "Explosive and Dangerous Dusts," gave a very clear outline of the subject. I shall, therefore, refrain from giving a series of experiments similar to those performed by him at the time, but shall directly go on to show that dust explosions in breweries may be largely prevented, and how, when they do occur, the explosive force and fire may be restricted to the mill-room.

The cause of the explosions in breweries is, that when grain dust becomes finely divided a certain degree of fineness is reached at which it may, on the slightest provocation, be almost instantaneously ignited, as for example, by the spark of a striking piece of iron, the products of the almost instantaneous combustion being gases of many hundred times the volume of the former dust, causing, by their expansion, the terrific force of these explosions. With the present arrangement of malt mills in breweries explosions and fires of this nature are not restricted to the mill-room, but spread through the elevators and openings, throughout the entire brewery, generally occasioning heavy losses. One of the greatest defects of the present system is that of having the mill inside of the main brewery building. This should be placed outside. It is just as dangerous, if not more so, to have the malt-mill in a brewery as it would be to have the picker of a shoddy mill in the main building. The first and cardinal change from the present system should be as follows:

The mill should be situated outside of the main brewery, in a separate building, all communicating openings between the mill-house and main building being closed by iron-lined doors, with stone sills, and the doors should be self-closing.

Having considered this defect we must next turn our attention to the construction of the mill-room, and the mill itself.

At present the malt-mill of the ordinary type consists of a cleaning

apparatus, frequently for dust only, a pair of chilled iron or steel rolls, sometimes corrugated, motion being imparted to but one, the other being turned by friction. The crushed grain drops from the rolls into the elevator cups and is then carried to the grain bin, generally situated on one of the higher floors. Now, let us closely look at this arrangement and examine its defects. The malt after passing through, even the best cleaner, still contains extraneous particles of iron, but with the ordinary cleaning apparatus the grain is full of such particles as stones, iron nails, bits of wire, from "self-binders and reapers," matches, and I was even informed of a case where a loaded pistol cartridge was happily detected before passing into the mill. In case a piece of iron comes between the revolving rolls it is apparent that a spark is readily created, which instantly inflames the finely divided dust in the mill-box, causing an explosion and fire. But the explosion must find vent somewhere, so it travels up the elevator boot, being in fact sucked up the boot by the upward draft in it, caused by the upward motion of the cups, acting like so many fans. The boot which is filled with very dry dust, having lost much moisture by passing through the rolls, is thereby also ignited, carries the fire from story to story, while the elevator-box, which is almost without exception, of wood, is rapidly burned through, and thus an entire building may become a prey to the flames. Having considered the defects of a system which has of late caused most of our brewery fires, let us next consider how to overcome them.

The grain should be thoroughly cleaned before passing into the mill; this may be accomplished by a number of devices, the simplest being a cylindrical (or hexagonal) screen with meshes of unequal sizes. One-half contains meshes large enough to allow dust to pass, while in the other half the size of the meshes is increased so as to allow the passage of grain, retaining, however, all larger and irregularly formed foreign matter. The grain, after passing into the cylinder, is rolled about by the revolution of the screen; the malt dust falls through the small meshes, the grain passes into the second half containing the larger meshes, where larger foreign matter is retained, and shot out into a bag at the other end, while the grain falling through the meshes drops into the rolls. Many other, but more complicated, processes may be employed for this purpose, among which may be mentioned those of Haas & Parson and Schwalbe & Son.

The latter, which also, besides cleaning, classifies the grain, is deserv-

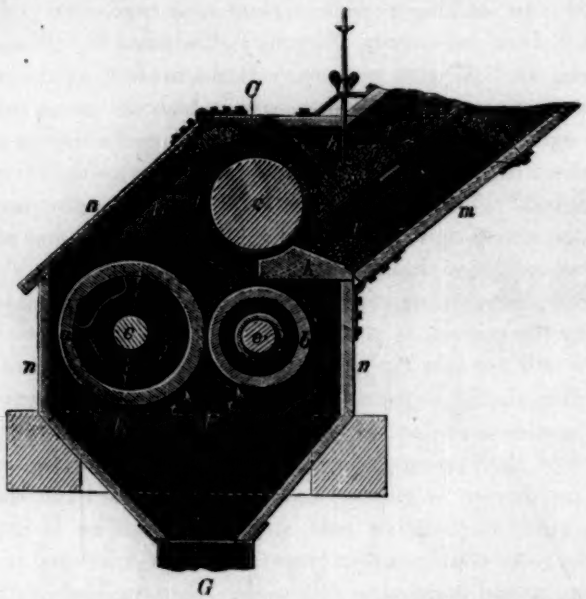
ing of special mention; although it has in Germany been almost exclusively employed to clean and classify the grain before malting, yet it would be an excellent cleaner for malt before milling, as it would be very desirable to mill malt of one size and quality (which varies with the size) at one time, both for *setting* the mill and for better results in the "mash." [*Representations of various cleaning machinery were here thrown on the screen and explained.*]

Grain should be especially well cleaned of *all* iron particles, as it is these which—by striking a spark—create most explosions and fires in malt mills. Iron can only be effectually eliminated from the grain by a *strong* magnet. A weak magnet will not answer, as the magnetic force must overcome the momentum with which the grain runs down the spout into the mill. Magnets may be arranged either in the form of horse shoes through which the grain runs, or as a single very strong "plate magnet." The latter method is preferable, as the number of smaller horse shoe magnets will not have the same amount of attractive force as *one* large plate magnet.

The grain, after being well cleaned and all the remaining iron removed by the magnet, is passed into the rolls. As these are well known, we will not take the space to describe them here, but simply state that they should be gearing, *not friction rolls.* In the case of friction rolls, motion is imparted to but one roll, the other being turned by the friction of the passing grain. In gearing rolls, to the contrary, the rolls are driven by gearing, and therefore both have their own motive power. In the first case, a piece of iron or stone coming between the rolls would cause a large amount of frictional heat, producing a spark and perhaps an explosion. In the second case the rolls, by the motive power which both have, would be more likely to have sufficient power to crush or flatten any extraneous particle without the production of enough frictional heat to cause an explosion. To still lessen the chances for the creation of heat the rolls should be held together by powerful springs, strong enough to allow grain to be crushed, but separating on the entrance of some harder body, such as a piece of stone or iron. At present most malt mills, and, with one exception, all malt mills in Philadelphia have their rolls held together by "set screws," which are arranged so as to set the rollers at any desirable distance apart; in case a hard extraneous substance comes between the rolls there is no "*give*," the only chance of stopping the

enormous friction between the hard substance and rolls will consist in the breaking of the screws or the crushing of the substance.

The great danger in malt mills is that, in case of an explosion, the explosive force and fire is not confined to the mill only, but runs from the mill into the elevator, and from there is distributed over the entire building. To check the force and fire of an explosion we must put a barrier between the mill-box and the elevator. This can best be accomplished by placing a receiving hopper below the rolls, kept well



filled while the mill is in operation, and from this hopper feed into the elevator cups. We thereby have a barrier of meal between the elevator and the mill, a barrier almost as effective as one of sand. But the important point in this case will be to keep the hopper well filled, for a hopper which is not full merely acts as a conduit and not as a barrier to an explosion. In order that the attendant of a mill shall not be relied upon, the receiving hopper should be kept filled automatically. For this purpose I suggested the following device, shown in the cut, (Fig. 1); a device which was not a new invention, but an adaptation of something well known, for a new purpose. A "feeder" for grain mills used for a long time in Germany is shown in cut, e and e^1 being the rolls of the mill, n, n, being the mill-box, while G is the

spout ordinarily leading into the elevator boot in mills properly constructed, into a receiving hopper; *c* is a roll of wood usually covered with a covering, and teeth *d* of steel projecting from 2 to 3 millimeters, we propose to use a covering and teeth of copper, phosphor bronze, or some other metal which will strike no sparks; *l* is an inclined plane of metal with sieve-like perforations large enough to allow dust to drop through them; *h* is a gauge which regulates the flow of grain on to the feeding roll *c*; l^1 is a "dust chamber," which may be made of any size, and which may be cleaned out through the door *m*; *k* is the receiving block of wood covered with copper, and at a distance of 1.9 millimeters from the teeth of the feeding roll. The operation of this feeder, which is a Belgian invention, and which has been used with great success in Germany, is very simple. The grain after passing through a cleaner drops on to the incline, is there separated from any remaining dust; and is then allowed to run in a thin stream—regulated by the gauge—on to the receiving block, where it is fed into the mill by the revolution of the feeding roll. We propose to utilize this invention, modified as above, to keep our receiving hopper at all times full. The crushed grain instead of falling directly into the elevator cups on leaving *G*, will fall into a receiving hopper, from which a pipe or incline (without perforations) leads the meal past a gauge, on to a feeder as described above, where the meal is fed into a smaller hopper, from which it drops into the elevator. On setting up a mill the relative points for both gauges will be determined, the grain-feeder and the mill will be set in motion while the *discharger* will remain at rest until the receiving hopper is filled, when it will also be set in motion; this operation will be performed by the erecting machinist; for after the first grinding the receiving hopper will always be full, as the grain will be fed in just as rapidly at the top as the meal is discharged at the bottom. The only case in which the receiving hopper could become empty is one, which would very rarely occur in a well-conducted brewery; that is when the mill is running while no grain is on the incline. When this does occur the above described process must be repeated.

The receiving hopper and elevator should be lined, so that in case of fire the flames may be restricted to them. The lining of the elevator box should, however, not be of iron but copper, as the elevator cups, on striking against an iron lining, might readily create a spark.

That the force of explosions may be spent without harming the

building, large vent pipes—leading into the open air—should be introduced into the mill-box. Iron pipes closed on the outside by caps, similar to our common stove pipe hole caps—which in case of an explosion would be readily blown off—would be the most effectual.

Steam jets should be introduced into both the mill-box and elevator. One of our breweries has extinguished two explosive malt mill fires by this means.

The compartment appropriated for the use of the malt mill should be well lighted, so that no artificial light may be required on the cloudiest day. Where night work is in vogue, or where artificial light is required for day work, the light should be enclosed, and *under no condition should loose candles or coal oil lamps* be employed.

I will not take up your valuable time in describing other minor devices, which I have invented, such as an automatic contrivance by which I close all communicating openings between the mill-house and the brewery, and turn on the steam by the pressure of the explosions. I am satisfied, however that in a brewery in which my system of milling is introduced, explosions will be almost entirely prevented, and when these do occur, they will be restricted to the mill-room without doing further harm.

Effect of Light upon Glass.—Some kinds of white glass become, in the process of time, more or less deeply colored under the influence of luminous rays. The most common tints are violet and green. The materials of ordinary glass are somewhat ferruginous and capable of tinging glass with a deep green shade by the protoxide of iron. In order to remove the coloring, peroxide of manganese is added, which changes the protoxide into a sesqui oxide, which gives a feeble reddish-yellow tint. It is almost impossible to observe the proper proportions of manganese and iron. If there is too much oxide of manganese the glass has at first a violet shade; if there is too much protoxide of iron the glass will be greenish; if all the manganese is reduced to the state of protoxide the glass is colorless. The influence of light and air may gradually bring about a partial oxidation of the protoxide of manganese and a violet coloring which increases with time. A shade which is due to an excess of manganese is observed in the Pinacothek, at Munich, where the upper windows of the picture gallery give a very marked violet light which produces a bad effect.—*Polyt. Ztg.* cited in *Chron. Indust.*, No. 41.

SCIENCE IN RELATION TO THE ARTS.

By C. William Siemens, F. R. S.

(Continued from page 66.)

The demand for ammonia may be taken as unlimited, on account of its high agricultural value as a manure; and, considering the failing supply of guano and the growing necessity for stimulating the fertility of our soil, an increased production of ammonia may be regarded as a matter of national importance, for the supply of which we have to look almost exclusively to our gas works. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia; which taken at 20*l.* 10*s.* a ton, represents an annual value of 1,947,000£.

The total annual value of the gas works by-products may be estimated as follows:

Coloring matter,	£3,350,000
Sulphate of ammonia,	1,947,000
Pitch (325,000 tons)	365,000
Creosote (25,000,000 gallons)	208,000
Crude carbolic acid (1,000,000 gallons)	100,000
Gas coke, 4,000,000 tons (after allowing 2,000,000 tons consumption in working the retorts) at 12*s.*	2,400,000
Total	£8,370,000

Taking the coal used, 9,000,000 tons at 12*s.*, equal 5,400,000*l.*, it follows that the by-products exceed in value the coal used by very nearly 3,000,000*l.*

In using raw coal for heating purposes these valuable products are not only absolutely lost to us, but in their stead we are favored with those semi-gaseous by-products in the atmosphere too well known to the denizens of London and other large towns as smoke. Professor Roberts has calculated that the soot in the pall hanging over London on a winter's day amounts to fifty tons, and that the carbonic oxide, a poisonous compound, resulting from the imperfect combustion of coal, may be taken as at least five times that amount. Mr. Aitken has shown, moreover, in an interesting paper communicated to the Royal Society of Edinburgh, last year, that the fine dust resulting from the imperfect combustion of coal is mainly instrumental in the formation

of fog; each particle of solid matter attracting to itself aqueous vapor; these globules of fog are rendered particularly tenacious and disagreeable by the presence of tar vapor, another result of imperfect combustion of raw fuel, which might be turned to much better account at the dye-works. The hurtful influence of smoke upon public health, the great personal discomfort to which it gives rise, and the vast expense it indirectly causes through the destruction of our monuments, pictures, furniture, and apparel, are now being recognized, as is evinced by the success of recent Smoke Abatement Exhibitions. The most effectual remedy would result from a general recognition of the fact that wherever smoke is produced, fuel is being consumed wastefully, and that all our calorific effects, from the largest down to the domestic fire, can be realized as completely and more economically, without allowing any of the fuel employed to reach the atmosphere unburnt. This most desirable result may be effected by the use of gas for all heating purposes with or without the addition of coke or anthracite.

The cheapest form of gas is that obtained through the entire distillation of fuel in such gas producers as are now largely used in working the furnaces of glass, iron, and steel works; but gas of this description would not be available for the supply of towns owing to its bulk, about two-thirds of its volume being nitrogen. The use of water-gas, resulting from the decomposition of steam in passing through a hot chamber filled with coke, has been suggested, but this gas also is objectionable, because it contains, beside hydrogen, the poisonous and inodorous gas carbonic oxide, the introduction of which into dwelling-houses could not be effected without considerable danger. A more satisfactory mode of supplying heating separately from illuminating gas would consist in connecting the retort at different periods of the distillation with two separate systems of mains for the delivery of the respective gases. Experiments made some years ago by Mr. Ellisen of the Paris gas works have shown that the gases rich in carbon, such as olefiant and acetylene, are developed chiefly during an interval of time, beginning half an hour after the commencement and terminating at half the whole period of distillation, whilst during the remainder of the time, marsh gas and hydrogen are chiefly developed, which, while possessing little illuminating power, are most advantageous for heating purposes. By resorting to improved means of heating the retorts with gaseous fuel, such as have been in use at the Paris gas

works for a considerable number of years, the length of time for effecting each distillation may be shortened from six hours, the usual period in former years, to four, or even three hours, as now practiced at Glasgow and elsewhere. By this means a given number of retorts can be made to produce, in addition to the former quantity of illuminating gas of superior quality, a similar quantity of heating gas, resulting in a diminished cost of production and an increased supply of the valuable by-products previously referred to. The quantity of both ammonia and heating gas may be further increased by the simple expedient of passing a streamlet of steam through the heated retorts towards the end of each operation, whereby the ammonia and hydrocarbons still occluded in the heated coke will be evolved, and the volume of heating gas produced be augmented by the products of decomposition of the steam itself. It has been shown that gas may be used advantageously for domestic purposes with judicious management even under present conditions, and it is easy to conceive that its consumption for heating would soon increase, perhaps tenfold, if supplied separately at say 1*s.* a thousand cubic feet. At this price gas would be not only the cleanest and most convenient, but also the cheapest form of fuel, and the enormous increase of consumption, the superior quality of the illuminating gas obtained by selection, and the proportionate increase of by-products, would amply compensate the gas company or corporation for the comparatively low price of the heating gas.

The greater efficiency of gas as a fuel results chiefly from the circumstance that a pound of gas yields in combustion 22,000 heat units, or exactly double the heat produced by combustion of a pound of ordinary coal. This extra heating power is due partly to the freedom of the gas from earthy constituents, but chiefly to the heat imparted to it in effecting its distillation. Recent experiments with gas-burners have shown that in this direction also there is much room for improvement.

The amount of light given out by a gas flame depends upon the temperature to which the particles of solid carbon in the flame are raised, and Dr. Tyndall has shown that of the radiant energy set up in such a flame, only the $\frac{1}{25}$th part is luminous; the hot products of combustion carry off at least four times as much energy as is radiated, so that not more than one hundredth part of the heat evolved in combustion is converted into light. This proportion could be improved

however, by increasing the temperature of combustion, which may be effected either by intensified air currents or by regenerative action. Supposing that the heat of the products of combustion could be communicated to metallic surfaces, and be transferred by conduction or otherwise to the atmospheric air supporting combustion in the flame, we should be able to increase the temperature accumulatively to any point within the limit of dissociation; this limit may be fixed at about 2,300° C., and cannot be very much below that of the electric arc. At such a temperature the proportion of luminous rays to the total heat produced in combustion would be more than doubled, and the brilliancy of the light would at the same time be greatly increased. Thus improved, gas-lighting may continue its rivalry with electric lighting both as regards economy and brilliancy, and such rivalry must necessarily result in great public advantage.

In the domestic grate, radiant energy of inferior intensity is required, and I for one do not agree with those who would like to see the open fireplace of this country superseded by the continental stove. The advantages usually claimed for the open fireplace are, that it is cheerful, 'pokable,' and conducive to ventilation, but to these may be added another of even greater importance, viz. that the radiant heat which it emits passes through the transparent air without warming it, and imparts heat only to the solid walls, floor, and furniture of the room, which are thus constituted the heating surfaces of the comparatively cool air of the apartments in contact with them. In the case of stoves the heated air of the room causes deposit of moisture upon the walls in heating them, and gives rise to mildew and germs injurious to health. It is, I think, owing to this circumstance that upon entering an apartment one can immediately perceive whether or not it is heated by an open fireplace; nor is the unpleasant sensation due to stove-heating completely removed by mechanical ventilation; there is, moreover, no good reason why an open fireplace should not be made as economical and smokeless as a stove or hot-water apparatus.

In the production of mechanical effect from heat, gaseous fuel also presents most striking advantages, as will appear from the following consideration. When we have to deal with the question of converting mechanical into electrical effect, or *vice versâ*, by means of the dynamo-electrical machine, we have only to consider what are the equivalent values of the two forms of energy, and what precautions are necessary to avoid losses by the electrical resistance of conductors and by

friction. The transformation of mechanical effect into heat involves no losses except those resulting from imperfect installation, and these may be so completely avoided that Dr. Joule was able by this method to determine the equivalent values of the two forms of energy. But in attempting the inverse operation of effecting the conversion of heat into mechanical energy, we find ourselves confronted by the second law of thermo-dynamics, which says that whenever a given amount of heat is converted into mechanical effect, another but variable amount descends from a higher to a lower potential, and is thus rendered unavailable.

In the condensing steam engine this waste heat comprises that communicated to the condensing water, whilst the useful heat, or that converted into mechanical effect, depends upon the difference of temperature between the boiler and condenser. The boiler pressure is limited, however, by considerations of safety and convenience of construction, and the range of working temperature rarely exceeds 120° C. except in the engines constructed by Mr. Perkins, in which a range of 160° C., or an expansive action commencing at 14 atmospheres, has been adopted with considerable promise of success, as appears from an able report on this engine by Sir Frederick Bramwell. To obtain more advantageous primary conditions we have to turn to the caloric or gas engines, because in them the co-efficient of efficiency expressed by $\frac{T-T'}{T}$, may be greatly increased. This value would reach a maximum if the initial absolute temperature T could be raised to that of combustion, and T′ reduced to atmospheric temperature, and these maximum limits can be much more nearly approached in the gas engine worked by a combustible mixture of air and hydro-carbons than in the steam engine.

Assuming, then, in an explosive gas engine a temperature of 1,500° C. at a pressure of 4 atmospheres, we should, in accordance with the second law of thermo-dynamics, find a temperature after expansion to atmospheric pressure of 600° C., and therefore a working range of $1{,}500° - 600° = 900°$, and a theoretical efficiency of $\frac{900}{1500+274}$ = about one-half, contrasting very favorably with that of a good expansive condensing steam engine, in which the range is $150 - 30 = 120°$ C., and the efficiency $\frac{120}{150+274} = \frac{2}{7}$. A good

expansive steam engine is therefore capable of yielding as mechanical work $\frac{2}{7}$th part of the heat communicated to the boiler, which does not include the heat lost by imperfect combustion, and that carried away in the chimney. Adding to these, the losses by friction and radiation in the engine, we find that the best steam engine yet constructed does not yield in mechanical effect more than $\frac{1}{7}$th part of the heat energy residing in the fuel consumed. In the gas engine we have also to make reductions from the theoretical efficiency, on account of the rather serious loss of heat by absorption into the working cylinder, which has to be cooled artificially in order to keep its temperature down to a point at which lubrication is possible; this, together with frictional loss, cannot be taken at less than one-half, and reduces the factor of efficiency of the engine to $\frac{1}{4}$th.

It follows from these considerations that the gas or caloric engine combines the conditions most favorable to the attainment of maximum results, and it may reasonably be supposed that the difficulties still in the way of their application on a large scale will gradually be removed. Before many years have elapsed we shall find in our factories and on board our ships, engines with a fuel consumption not exceeding 1 pound of coal per effective horse power per hour, in which the gas producer takes the place of the somewhat complex and dangerous steam boiler. The advent of such an engine and of the dynamo-machine must mark a new era of material progress at least equal to that produced by the introduction of steam power in the early part of our century. Let us consider what would be the probable effect of such an engine upon that most important interest of this country—the merchant navy.

According to returns kindly furnished me by the Board of Trade and "Lloyds' Register of Shipping," the total value of the merchant shipping of the United Kingdom may be estimated at 126,000,000£. of which 90,000,000£. represent steamers having a net tonnage of 3,003,988 tons; and 36,000,000*l.* sailing vessels, of 3,688,008 tons. The safety of this vast amount of shipping, carrying about five-sevenths of our total imports and exports, or 500,000,000£. of goods in the year, and of the more precious lives connected with it, is a question of paramount importance. It involves considerations of the most varied kind: comprising the construction of the vessel itself, and the material employed in building it; its furniture of engines, pumps, sails, tackle, compass, sextant, and sounding apparatus, the preparation

of reliable charts for the guidance of the navigator, and the construction of harbors of refuge, lighthouses, beacons, bells, and buoys, for channel navigation. Yet notwithstanding the combined efforts of science, inventive skill, and practical experience—the accumulation of centuries—we are startled with statements to the effect that during last year as many as 1,007 British-owned ships were lost, of which fully two-thirds were wrecked upon our shores, representing a total value of nearly 10,000,000£. Of these ships 870 were sailing vessels and 137 steamers, the loss of the latter being in a fourth of the cases attributable to collision. The number of sailing vessels included in these returns being 19,325, and of steamers 5,505, it appears that the steamer is the safer vessel, in the proportion of 4·43 to 3·46; but the steamer makes on an average three voyages for one of the sailing ship taken over the year, which reduces the relative risk of the steamer as compared with the sailing ship per voyage in the proportion of 13·29 to 3·46. Commercially speaking, this factor of safety in favor of steam-shipping is to a great extent counterbalanced by the value of the steamship, which bears to that of the sailing vessel per net carrying ton the proportion of 3·1, thus reducing the ratio in favor of steam shipping as 13·29 to 10·38, or in round numbers as 4 to 3. In testing this result by the charges of premium for insurance, the variable circumstances of distance, nature of cargo, season and voyage have to be taken into account; but judging from information received from shipowners and underwriters of undoubted authority, I find that the relative insurance paid for the two classes of vessel represents an advantage of 30 per cent. in favor of steam-shipping, agreeing very closely with the above deductions derived from statistical information.

In considering the question how the advantages thus established in favor of steam-shipping could be further improved, attention should be called in the first place to the material employed in their construction. A new material was introduced for this purpose by the Admiralty in 1876–78, when they constructed at Pembroke dockyard the two steam corvettes, the *Iris* and *Mercury*, of mild steel. The peculiar qualities of this material are such as to have enabled shipbuilders to save 20 per cent. in the weight of the ship's hull, and to increase to that extent the carrying capacity. It combines with a strength 30 per cent. superior to that of iron, such extreme toughness, that in the case of collision the side of the vessel has been found to yield or bulge several feet without showing any signs of rupture, a quality affecting

the question of sea risk very favorably. When to the use of this material there are added the advantages derived from a double bottom, and from the division of the ship's hold by means of bulkheads of solid construction, it is difficult to conceive how such a vessel could perish by collision either with another vessel or with a sunken rock. The spaces between the two bottoms are not lost, because they form convenient chambers for water ballast, but powerful pumps should in all cases be added to meet emergencies.

The following statement of the number and tonnage of vessels building and preparing to be built in the United Kingdom on the 30th of June last, which has been kindly furnished me by Lloyd's, is of interest as showing that wooden ships are fast becoming obsolete, and that even iron is beginning to yield its place, both as regards steamers and sailing ships, to the new material mild steel; it also shows that by far the greater number of vessels now building are ships of large dimensions propelled by engine power:

	Mild Steel		Iron		Wood		Total	
	No.	Tons gross	No.	Tons gross	No.	Tons gross	No.	Tons gross
Steam	89	159,751	555	929,921	6	460	650	1,090,132
Sailing	11	16,800	70	120,259	49	4,635	130	141,694
	100	176,551	625	1,050,180	55	5,095	780	1,232,826

If to the improvements already achieved could be added an engine of half the weight of the present steam engine and boilers, and working with only half the present expenditure of fuel, a further addition of 30 per cent. could be made to the cargo of an Atlantic propeller vessel—no longer to be called a steamer—and the balance of advantages in favor of such vessels would be sufficient to restrict the use of sailing craft chiefly to the regattas of this and neighboring ports.

The admirable work on the "British Navy," lately published by Sir Thomas Brassey, the Civil Chief Lord of the Admiralty, shows that the naval department of this country is fully alive to all improvements having regard to the safety as well as to the fighting qualities of Her Majesty's ships of war, and recent experience goes far to prove that although high speed and manœuvering qualities are of the utmost value, the armor plate which appeared to be fast sinking in public favor is not without its value in actual warfare.

(To be continued.)

A SUMMARY OF PROGRESS IN SCIENCE AND INDUSTRY, 1882.

[From the Report of the Secretary, January 17, 1883.]

Like its immediate predecessor, the year 1882 was not characterized by the announcement of any great or revolutionizing discoveries, or industrial processes, but rather by the steady and satisfactory advance in the arts and sciences, and by general industrial activity and business prosperity. I give below a brief summary of the more notable facts and events that appear to be worthy of special mention before the Franklin Institute in recording the progress of the past year.

In constructive engineering there is little to record during the year 1882, save the fact that considerable progress was made towards the completion of the superstructure of the bridge across the East river and upon the tunnel beneath the Hudson. The Channel tunnel scheme has met with a serious set-back, singularly enough, by reason of an agitation based upon political considerations. Concerning the condition of work upon the interoceanic canal at Panama, in the absence of reliable information, nothing can be said. It appears probable, however, that considerable preliminary work has been accomplished. Considerable interest was aroused in the engineering fraternity during the past year, by reason of the investigation by a commission of government engineers, appointed by the Secretary of the Treasury, of a theory of steam boiler explosions with which the name of Mr. D. T. Lawson, of Wellsville, Ohio, is prominently identified. The theory in question is substantially that steam boilers explode by the sudden abstraction (by whatever means) of a considerable volume of steam, which, by relieving the superheated water in the boiler of pressure, causes it to instantly burst into steam; this, meeting with the sudden check offered by the resistance of the confining shell of the boiler, produces a concussive effect upon every square inch of the boiler much greater than the normal steam pressure, and frequently sufficient to cause the boiler to explode with violence.

In several trials by this commission, it was demonstrated that steam boilers could be violently exploded at pressures far below those which they had previously withstood without injury, by simply providing means for the sudden removal of the steam from the steam space. While there are some differences of opinion as to whether the experi-

mental device employed in these trials did not considerably exaggerate the conditions that may be conceived to be brought about in practice, it will be generally conceded that Mr. Lawson has laid the engineering world under obligations by properly formulating and bringing into prominence a real and active factor in the possible causation of steam boiler explosions, which the mechanical world has hitherto ignored. As a safeguard against this danger, Mr. Lawson has proposed an arched perforated diaphragm, fixed horizontally in the boiler near the water-line, and supplied with valves under the control of the engineer. The object of this device is to retard the time of the passage of steam from the water compartment into the steam compartment, and thus prevent instantaneous removal of pressure from the water. I may add in conclusion, that the government commission in its report indorsed the theoretical views of Mr. Lawson, and the efficiency of his system of boiler construction.

Some attention was attracted during the year to the experiment of operating street cars upon the cable system of propulsion which has been going on during the past year in Chicago. This system has been in successful operation for some years in San Francisco, and the Chicago experiment is pronounced to have been so satisfactory that it has been considerably extended. A similar road was also laid down in Philadelphia during the year, and is now about going into operation. It is not at all unlikely that this system may come in time to be generally adopted.

The interest in the subject of electric lighting during the past year continued unabated. The practical availability of the system of arc lights for the lighting of large buildings and streets, may now be considered as fully demonstrated, and the public interest is concentrated upon the adaptability of the several plans employing incandescent lamps, for domestic purposes, to take the place of gas. By far the most important experiment of this nature that has yet been attempted, is that of the Edison system in New York, and which has been in operation over a considerable district, in the lower part of the city named, during the greater part of the year. Thus far, however, it has been impossible to learn from authoritative sources anything respecting the important question of cost of producing the light, upon which the success of the company and the further extension of the system will depend. It would be unjust, in view of the importance of this experiment, to interpret the silence of the company unfavorably, as has been

done in the newspapers, and I shall therefore pass the subject by without further comment.

The present year will doubtless witness the demonstration of the feasibility of domestic lighting, since public announcement has lately been made that an experiment upon the large scale, similar to that of the Edison, is about to be made by the plan of employing secondary batteries, which will be furnished to each building, and will be charged to saturation from a central station during the hours when light is not required, and which will be capable of supplying the maximum number of lights that will be required. The cost of a plant for this system will be very much less than that of the direct supply system, and the current sent to the lamps being quite free from variations of intensity, the difficulty from the breakage of lamps, it is claimed, will be reduced to a minimum.

During the past year secondary batteries upon the Faure system have been applied practically for lighting railway carriages both in England and in this country; and, without implying the necessary failure of other systems, I think it safe to say that the ultimate success of the electric light as a practical competitor of gas will depend largely upon the perfection of the secondary battery.

I had occasion in my last year's summary to characterize the year 1881 (during which nearly 8,000 miles of new railroad were constructed in the United States), as a phenomenal year; but in this respect it must yield the palm to the year just passed, during which the enormous aggregate of not less than 11,000 miles of new road was added to the railway systems of the country. There are evidences, however, that the climax has been reached, and that the present year will show a notable diminution in railway extension.

In the production of iron and coal, the two most prominent indicators of our industrial condition, the figures of the past year will probably be found not to vary materially from those of the year 1881, which, in both these factors, exceeded those of any previous year of our history.

The figures of the production of the precious metals in 1882 show a slight decrease as compared with those of 1881.

The successful establishment of the beet sugar industry in the United States, as demonstrated by the profitable operations of the Alvarado factory in California during the past year, is a subject for congratulation, as being the first promising indication that the difficulties surrounding the domestication of this important industry have been successfully overcome.

The introduction into the United States of the Solvay process for manufacturing soda, commonly known as the ammonia-soda process, is also worthy of special note as an important industrial event. The glucose industry has fully maintained the phenomenal rate of increase that has hitherto distinguished it, and one establishment of really colossal proportions has been erected in Chicago during the past year, and is just now about being put in operation.

The statement has been extensively circulated during the past year, on the alleged authority of Sir Henry Bessemer, that a new process for producing the metal aluminium was being experimented with, giving very promising results, which would enable this metal to be produced at nominal cost. Thus far no details respecting this much-to-be desired process have been made public.

One of the most interesting technical suggestions advanced during the past year, was that of Mr. Mosely before the British Iron and Steel Institute, to do away with the use of gunpowder, or other explosives, in breaking down coal in the mine, and thus avoid the danger of igniting fire-damp, and other dangers and inconveniences attending the present methods. For this purpose Mr. Mosely employs lime, consolidated into cartridges by a hydraulic pressure of 40 tons. By a simple and inexpensive method these cartridges are confined in the bore holes in such a manner that when a quantity of water is forced into contact with them, the combined effect of the steam generated and the expansion of the lime in slaking, the coal is broken clean from the roof in from 10 to 15 minutes. By this method the amount of wastage from small coal, which is ordinarily very considerable, is reduced to a minimum, as nearly all the coal falls in large masses. It completely avoids the danger of igniting fire-damp, and instead of vitiating the atmosphere of the mine, exerts a most grateful influence in purifying it. The method is said to work like a charm, and has already been introduced with much satisfaction in some of the Derbyshire mines in England, and into certain Belgian collieries.

The manner in which the solar heat is maintained has always been a vexed question with physicists and astronomers; all, however, have hitherto agreed that whatever its origin, the solar heat could not be indefinitely maintained, and that the sources of the seemingly exhaustless floods of energy our central orb has been radiating into space for countless ages, must be continually, though imperceptibly, diminishing; that the time must infallibly come—though indefinitely remote

—when the diminished intensity of the solar emanations would no longer suffice to sustain life upon the earth; and that the ultimate fate of our solar system was to be reduced to the condition of an aggregation of dark, cold and lifeless planets with their satellites, circling about a dark and burned-out sun.

This view, it is interesting to note, has been challenged during the past year by Dr. C. W. Siemens. He considers that the interstellar spaces are filled with gaseous matter—hydrogen, hydro-carbons, oxygen, etc.—in a very attenuated condition; that these gases are attracted in enormous quantities towards the polar surfaces of the sun, passing, in their approach to the solar surface, from a condition of extreme tenuity and cold, to that of compression, accompanied with rise of temperature; that, finally, on reaching the photosphere, they burst into flames, giving rise to a great development of heat; and that the products of combustion—aqueous vapor, carbonic oxide and anhydride—yielding to the influence of centrifugal force, will flow towards the solar equator and thence be projected into space. He holds it to be probable now, that solar radiation would step in to return these combustion products back again to their original condition by a process of dissociation carried on at the expense of that portion of the solar energy that is now supposed to be lost to our planetary system by radiation into space. This probability he bases upon experiments by which he has obtained unmistakable evidence of the dissociation of water vapor by the simple action of the solar rays. Upon this interesting and plausible hypothesis, therefore, the rays of our own, and of countless other suns that are traversing space, are made to perpetually renew the supply of fuel required for the maintenance of combustion upon the solar surface.

Though not unknown to physicists, the practical application of the spectroscope as a weather indicator, by the observation of the intensity of the so-called rain band (the absorption spectrum of aqueous vapor), which occupies a portion of the solar spectrum, has of late come to be quite generally known and practiced. Its indications are said to be infallible in enabling one to predict the occurrence or absence of rain, under some circumstances, for a day or two in advance. Rain-band spectroscopes have been constructed by certain opticians, so small that they may be carried in the pocket, but so powerful and true that a glance of two seconds through them suffices to tell an experienced observer the general condition of the whole atmosphere.

In November of the past year occurred the hundredth anniversary

of the first experiments of the Montgolfier brothers, at Avignon, in France, with balloons. The occasion was duly observed by the several European aeronautical societies. The principal interest of this circumstance to us, is the opportunity it affords us of noting how little has actually been accomplished in a century towards perfecting the art of aerial navigation. With the exception of some trifling improvements in the construction of the balloon, and a few questionably successful efforts in directing its course, the art of aerial navigation stands, for practical purposes, where the Montgolfiers and their contemporaries left it. With the perfection of the secondary battery, it is hoped that electric motors may soon be successfully applied to the directions of balloons; but thus far the problem of aerial navigation remains unsolved.

In geology, perhaps the most interesting event of the past year was the announcement by Prof. H. C. Lewis that he had succeeded in tracing the terminal moraine of the great ice sheet, that covered the northern portion of this continent during the glacial period, in Pennsylvania, for a distance of 400 miles across the great divide between the Atlantic and the Gulf of Mexico. The southern limit of the great ice sheet had previously been traced from Cape Cod across Rhode Island, Long Island, New Jersey, New York, Ohio, Indiana, and other States farther West; and Prof. Lewis' discovery fills out an important gap that has hitherto been missing, and completes the line of the moraine.

As the direct outgrowth of Pasteur's classical researches in establishing the germ theory of infectious diseases, we may refer to the announcement made during the past year, of the important discovery by Dr. Koch, of Berlin, of the bachterial or parasitic origin, and consequently the infectiousness of tubercular disease. Dr. Koch's conclusions were based upon a multitude of observations, in the course of which he demonstrated the invariable presence, in tuberculous material, of myriads of minute organisms possessing all the characteristics of bacilli, which he succeeded in identifying, and with which he also succeeded in transmitting tuberculous disease with all its characteristic symptoms to guinea-pigs, rabbits, and cats, by inoculation; and this was successfully done, not only by transferring the tuberculous matter from diseased animals to healthy ones, but by employing the purified bacilli which had been obtained by cultivation and reproduction in a pabulum, extending over a period of six months. Dr. Koch's researches seem to have all the force of demonstration, and his conclusions appear to have met with almost universal acceptance.

Book Notices.

THE ACTUAL LATERAL PRESSURE OF EARTHWORK. By Benjamin Baker, M.Inst.C.E. Reprinted from Minutes Proc. Inst. C.E., London. Van Nostrand's Science Series. Price, 50 cents.

This contribution to the theory of retaining walls is one of the most valuable that has appeared from the fact that it is a compilation of a large number of experiments, and of dearly-bought experience by one who has given the question considerable thought. The long analytical formulæ, so common in treatises on earth pressure, are usually misleading and disappointing. "One authority after another has simply evaded the task of experimental investigation by asuming that some of the elements affecting the stability of earthwork are so uncertain in their operations as to justify their rejection, and have so relieved themselves from further trouble." Mr. Baker has given only empirical inductions from the actual cases he has collected. The one regret we have to express refers to a want of systematic arrangement for better reference, which would have greatly enchanced the practical value of the book.

The conclusions finally arrived at, of course, do not differ much from common custom, but the proper limits which are given of thickness and batir under different conditions will be useful. It was found that the actual lateral thrust of good earthwork was less than ordinary text books would lead a student to infer, and, on the other hand, that by practical examples of dock and other walls, in actual works, a larger factor of satety was required to cover contingencies of various kinds and degrees. A proper discrimination, therefore, between the pressure of good earthwork alone and other conditions would tend sometimes to lessen, at other times to increase, the thickness of walls as ordinarily designated in books.

The paper is illustrated with a large number of cuts, and is followed by a discussion on the conclusions advanced by other eminent English authorities on the subject, who add results of their own experience, either endorsing or modifying those of the author.

Altogether we can, perhaps, nowhere else find such a wealth of facts within the same compass concerning the stability of retaining walls, and the practical engineer will seldom have to search in vain among them for a parallel case to his own. R. H.

AMERICAN FOUNDRY PRACTICE. Treating of loam, dry sand and green sand moulding, and containing a practical treatise upon the management of cupolas and the melting of iron. By Thomas S. West, practical Iron moulder and Foundry foreman, (fully illustrated) New York, John Wiley & Sons, 15 Astor Place, 1882.

This is a work such as only a practical moulder could write, and just the kind of a work needed by those engaged in the craft.

The subject, a very dry one, would not promise agreeable reading, but the way the author has handled it shows how a very great amount of instruction, even on so uninteresting a subject as moulding in sand, may be rendered pleasing reading matter. There is a vein of humor running through the information conveyed, which cannot help but interest the working moulder, and lead him to peruse its pages, when, if there was nothing beyond the mere information afforded by the subject, he would probably only refer to just such parts as for the moment were wanted.

The whole subject of moulding in green sand, in dry sand and in loam, is well handled, and numerous examples are given of how to mould patterns, selected for their known difficulty, as experienced by the author himself. Making castings with but small parts of patterns and cores without boxes. To be able to make castings from patterns finished in every detail, is not so very difficult a matter, but to be able to make good, serviceable castings with only a trowel, a few pieces of wood, and the foundry floor, shows a master hand worthy of the name of moulder. The author does not go so deep as this, but leads considerably farther in that direction than is generally practiced in the workshops of this country.

The chapters on contraction of castings, and feeding the moulds to prevent it, straining of the moulds, burning on of metal, and mixing and melting of iron, are well mapped out. The work is also interspersed with numerous wood-cuts, showing the manner in which certain work should be performed, making the author's meaning clearer. The illustrations showing improved forms of iron cupolas, air furnaces, foundry ladles, and ingot moulds, etc., are particularly good and valuable to all interested in the manufacture of iron and steel. The book successfully fills a want, and every mechanic would profit by reading it.

W. M. H

PAPERS ON MECHANICAL SUBJECTS. By Sir Joseph Whitworth, Bart. London: E. & F. N. Spon, 1883.

The recent discussion in our mechanical journals of methods and appliances for accurate measurement, which was evoked by the completion of the very ingenious Rogers-Bond Comparator, lends a special interest to the reprint of a number of Sir Joseph Whitworth's writings which have recently been published under the title of "Papers on Mechanical Subjects." Volume I, that is now before us, treats of:—"True Planes, Screw Threads, and Standard Measures." The papers here reproduced, some six in number, were most of them read at different times before various scientific societies, during the period from 1840 to 1881, and they afford an interesting illustration of the persistence with which their author has preached the doctrines of standards and interchange ability. The British "Board of Trade" has recently crowned his labors by adopting his gauges as the final standards to which local authorities may compare any gauges which may be submitted for inspection. It is hoped by this means to establish throughout the workshops of the country an identity in the unit of measurement which will conduce to greater accuracy of workmanship and vastly increase the possibilities of interchangeable manufacturing. The success or failure of this effort will, however, depend largely upon the accuracy of the standards selected; and recent investigations lead us to think that it is by no means certain that Whitworth's gauges are good enough to accomplish all that the Board of Trade expects of them.

This step on the part of the Government is, of course, a triumph for Whitworth, and an acknowledgment for which he has long striven.

In the preface to the little book before us, he says: "It is in consequence of this official recognition of the Gauges, which constitutes the last step in the direction of accurate measurement, and the means by which increased simplicity and economy of manufacture have been rendered possible, that I have determined to bring together in a permanent form the papers descriptive of the earlier stages by which this last step has been reached."

It is interesting to note that the preface also deplores with much reason the want of uniformity in sizes and the unnecessary multiplication of sizes in many branches of manufactures, and points out that a great economy in production and improvement in the product would result from the adoption by every manufacturer of the smallest number of patterns and sizes with which the wants of the consumer could be sat-

isfied. As a familiar example of this, the author alludes to candles—an illustration which comes home to every one who has had to whittle down a thirteen-sixteenth inch candle to get it into a three-fourth inch socket, or wrap paper around a small candle to make it stand straight in a stick an eighth of an inch too large. Whitworth says he found in *one* large candle works eleven sizes between six-tenths inch and one inch diameter, all of uncertain size, and none of them bearing any relation to the sockets of candlesticks, while the same range could be obtained with greater convenience by the use of five sizes between the same limits varying from each other by one-tenth of an inch.

The first of the papers is that on Plane Metallic Surfaces, and treats of scraped surface plates, which appear to have been a novelty in 1840 when this paper was read, the usual method then in vogue to attempt to produce true planes being by grinding. The author points out clearly the difference in the results obtainable by the two methods.

The interest attaching to this and the succeeding paper on screw threads, is largely historical, as they enable us to compare to some extent what was considered good practice forty years ago with that usual in the best shops of the present day. We can congratulate ourselves on a vast improvement, but undoubtedly there is still a wide field for further progress in the same direction. When Whitworth originated his screw thread system, he apparently assumed as axioms that it was inherently impossible to make a system that would meet the requirements of all users of screws, and that it was equally impossible to arrive at the proper proportions by deductive reasoning or mathematical analysis. His method was simply to find the average practice, and to do this he made an extensive collection of screw bolts from the principal workshops of England, and observed the average pitch for different diameters, noting particularly one-fourth, one-half, one, and one-and-one-half inches, and deviating from the exact average only when it was necessary to avoid inconvenient fractions. The angle of the thread was likewise determined by adopting fifty-five degrees, the average of the various angles used in different shops. No attempt was made to find a formula that would express the pitch in terms of the diameter. The table thus compiled covered screws from one-thirty-second inch to six inches diameter, while additional tables were made for pipe threads and for screws for watch and instrument makers, covering screws from one-hundredth inch to one-tenth of an inch.

In another paper here reprinted, Whitworth makes a plea for the

introduction in the workshop of a decimal division of the inch, because the convenient and natural binomial division he thinks does not afford a unit sufficiently small to express those differences of size which are necessary in fitting parts of machinery together, and he ridicules justly the use of such loose and dubious terms as "full" and "scant," arguing that a familiarity with the expression of sizes in thousandths or ten-thousandths of an inch would educate the mind to an exact appreciation of differences in size, and would conduce to increased accuracy in workmanship. It would, also, he thinks, enable the workman to put in permanent form the results of his experience and to impart his knowledge to others in precise terms. It is questionable, however, whether the adoption of such a system to the exclusion of that now in use would prove profitable. It would be highly impracticable to discard the usual shop and mercantile sizes of bar-iron for example, and yet to express eighths and sixteenths in three decimals would be perhaps, tedious and awkward. It certainly seems easier and quicker to say "three-eighths drill," than to speak of the same tool as a "drill of three hundred and seventy-five thousandths diameter." On the other hand, to introduce a new system of shop sizes founded upon the decimal division of the inch would involve an outlay for changes in gauges, reamers, drills, mandrils etc., that would practically be prohibitory.

In fact, the continued use of the ordinary nomenclature does not seem incompatible with great accuracy of expression, if we restrict the use of the decimals to expressing those sizes which cannot be exactly given in terms of the binomial division of the inch.

Whitworth also alludes to the difficulty of keeping shop tools up to size and enlarges upon the importance of having fixed standards with which to compare them. In his paper "On Measurement," he describes in general terms his well-known Micrometer Measuring Machine, with which he *claims* to read differences of size as small as one-millionth of an inch, by use of a "gravity piece," which will fall out if the screw is moved an amount which, by calculation of the gearing and screw would appear to be this minute quantity. Among the decimal tables given in this book is the Whitworth Wire Gauge, which its inventor offers as a substitute for the Birmingham and other gauges known to the trade. He proposes to call wire or metal plates by numbers, which shall mean their thickness expressed in thousandths of an inch; thus No. 12 would be twelve-thousandths inch thick, etc. Simple as this appears, it has not been widely adopted, and it is alleged against it, by

some, that while it entirely revolutionizes the present systems of numbering, it does not meet the requirements of the manufacturer. Other gauges give the smallest numbers to the greatest thicknesses, and then as each successive "pass" diminishes the thickness, the resulting product is called by a higher number. In these days of cheap micrometer callipers, it is not apparent to the mass of mankind why a simple expression of size, thickness, or diameter, in decimal parts of the inch would not answer all purposes of manufacture and sale with better results than can be obtained by fitting plates or wires into notches in a gauge. Unless indeed the use of a larger number of figures is found to be too cumbersome.

Whitworth, in these papers, tacitly assumes a degree of mechanical exactness for gauges of his manufacture, which, although it has been very generally conceded, may yet be proved not quite deserved, and it is confidently predicted that gauges will soon be manufactured in this country with an accuracy superior to that of Whitworth's celebrated make. Be this as it may, however, Whitworth has been so long regarded as a pre-eminent authority in mechanical matters that we cannot but read with respectful attention whatever he has written on subjects which have absorbed so much of the thought of his long life. We are gratified that these interesting papers have been put into accessible form, and hope that this volume will be followed by others from the same able pen. C. S., Jr.

Lockwood's Directory of the Paper, Stationery, and Printing Trades. Containing a List of Paper Manufacturers in the United States and Canada, and Paper and Paper Stock Dealers in the Principal Cities. New York, Howard Lockwood, Publisher, 1882; price $2.00.

The above partial title sufficiently describes the general scope of this octavo volume of about 450 pages, which must prove very useful to parties engaged in manufacturing paper or dealing therein, and in books and stationery. It has a list of the wholesale and retail booksellers and stationers throughout the United States and Canada, and a "complete list" of book, newspaper, job, and lithographic printers. The directory, which is conveniently arranged by States, cities, etc., contains 23,000 names, and has also the advantage of a very copious index. The whole arrangement—which includes good paper and typography—is excellent and creditable to the publisher. N.

Twinkling and Scintillation.—Karl Exner attributes the colored scintillation of stars to the combined influence of the regular dispersion of the rays and the irregular refractions in the atmosphere. The scintillation when near the horizon is colored, but uncolored when near the zenith.—*Wied. Ann.*, No. 10, 1882. C.

Insulite.—A new electrical insulator is described by *L'Industrie Belge*, to which the name of insulite has been given. The materials which enter into its composition are wood, sawdust, cotton rags, papier maché, and other fibrous substances. By a special treatment the materials are rendered proof against water and acids, and easy to work and shape in all forms. It can be employed in batteries, or as an insulator for telegraphic, telephonic, and illuminating wires. Its price is much less than that of ebonite or gutta percha.—*Chron. Industr.*, No. 37. C.

Caustic Lime in Coal Mining.—In answering some objections that have been urged against the efficiency of lime in coal mining, Paget Mosley says that he has found it to answer every purpose in respect of which gunpowder or wedging have been hitherto used. In the Shipley collieries, where the lime process has been in constant operation for many months, it is regularly applied to one of the hardest seams in the Midland coal-field, the toughest part of which is that next the roof, and this portion could never be got by wedging in the ordinary way, but had subsequently to be hacked down into slack. By the lime process, however, the coal is parted clean from the roof along the entire face operated on.—*Nature*, xxvi, 365. C.

Fire-proof Paint.—Vildé and Schambeck make a varnish of 20 parts of powdered glass, 20 parts porcelain, 20 parts powdered stone of any kind, 10 parts calcined lime, 30 parts soluble soda glass. The powders are made as fine as possible and sifted, and then thoroughly incorporated with the soluble glass, thus producing a syrupy mass, which can be employed as a varnish or mixed with colors for painting. The proportions of the solid ingredients may be varied at pleasure, but it is generally best to keep the indicated portion of lime. Silicate of potash may be substituted for the silicate of soda if desired. The first coating soon hardens and a second coat may be applied from six to twelve hours afterwards. Two coats are sufficient. The varnish may be employed as a preservative against rust.—*Chron. Industr.*, No. 39. C.

Evaporation of Quicksilver in a Vacuum.—H. Hertz has made some investigations of the evaporation of liquids, especially mercury, in a vacuum. The chief interest of his results is connected with the pressure of the vapor at the ordinary temperature of the air. According to his experiments, the pressure amounts to less than a thousandth of a millimetre (one-twenty-five thousandth of an inch). The insignificance of this pressure, rather than any special peculiarity of the quicksilver itself, must be the reason for the imperceptible influence which the quicksilver vapor, in Geissler tubes, produces upon the discharges.—*Wied. Ann.*, No. 10, 1882. C.

Use of Glycerine in Silvering Glass.—Some substances possess the property of reducing silver salts and thus producing an adhesive layer of brilliant metallic silver on the walls of the tubes which are used in the experiment, but unfortunately the mirror which is thus obtained is not perfect. Prof. Palmieri had the happy thought of employing glycerine, which seems likely to open a new future to the art of silvering. When glycerine is added to an ammoniacal solution of nitrate of silver, after a while the liquid becomes brown, then it deposits a black substance and becomes limpid and colorless. If the mixture is re-heated it takes a gradually deepening brownish hue; at the boiling temperature it becomes black and leaves upon the tube a metallic deposit of a steel gray color. If some drops of caustic potash are added to the mixture of glycerine and ammoniacal solution, after a short time there is a reduction of silver, which forms a very brilliant precipitate. If ether is added to this last mixture a metallic ring is formed almost instantly and in a few seconds the reduction is completed through the whole mass. The agitation of the liquid renders the reduction more uniform. If alcohol is substituted for the ether, the reduction is a little more rapid and the mirror very brilliant. The action of light and heat modify this reaction. Darkness favors the brilliancy and adhesiveness of the coating. The best result is obtained with caustic potash, when the mixture is between 60° and 70° (140° and 158° F.) with potash and ether, between 30° and 35° (86° and 95° F.) with potash and alcohol, between 40° and 45° (104° and 113°). The reaction is complete in eight or ten minutes. Prof. Palmieri promises a second note in which he will give the proportions of the different liquids which are necessary in order to yield the best result. —*Les Mondes*, Sep. 23, 1882. C.

Magnetic Observation during the Total Eclipse of May 17, 1882.—There is still some uncertainty as to the true cause of the abnormal magnetic variation, which is generally observed during solar eclipses. Is it a direct magnetic action of the two bodies which are in conjunction, or is it a simple effect of the variation of temperature and of atmospheric humidity, which ordinarily accompany the phenomenon? The observations at Zi-Ka-Wei, China, during the eclipse of May 17, 1882, seem to corroborate the second hypothesis and to remove all probability from the first. Marc Dechevrens, the director of the Zi-Ka-Wei observatory, reports his own observations upon that occasion, and confirms his conclusions by comparisons with observations upon the eclipses of 1868, at Célèbes, and 1878, at Denver. He finds additional confirmation from the disappointment of Dr. Little, an amateur astronomer of Shanghai, who was unable to make the observations which he expected on account of the cloudy sky. [These conclusions are confirmatory of the views recorded by Chase, in 1864. *Proc. Am. Phil. Soc.*, vol. ix; *Trans. Am. Phil. Soc.*, vol. xiii.] *L'Astronomie*, i, 270, C.

Electric Properties of Flames.—In 1827, Pouillet advanced the idea that the electricity of flame is due to the fact of combustion and, therefore, probably analagous to the electrification observed by Volta, on placing a burning coal or pastille upon the top of an electroscope. In 1854, Matteucci explained the phenomenon by supposing that the flame acted as an electrolyte upon the two metallic electrodes, in the same way as the acid between the two plates of a voltaic pile. This view accords with one which had been previously advanced by Hankel. Buff sought the explanation of the phenomenon in the thermoelectric difference of the two electrodes. Sir William Grove has shown that on bending a platinum wire, so that one of its ends touches the summit and the other the base of the flame, an electric current flows through the wire. At first glance this phenomenon seems to agree with Hankel's observation, that a flame is polarized longitudinally, but it is probable that all these explanations should be modified by considerations of the electric influence exercised by the envelope of heated air which surrounds the flame. Elster and Geitel have experimented with Thomson's quadrant electrometer and have found that the flame is not by itself a source of electricity; they regard the production of electricity as a thermo-electric phenomenon.—*L'Electricien*, Oct. 15, 1882. C.

Liquefaction of Ozone.—Hautfeuille and Chappuis compressed a mixture of oxygen and ozone, in Cailletet's apparatus, under a pressure of 125 atmospheres and at a temperature which was probably below —100° (—148°F.). When operating with a gas not containing more than 10 per cent of ozone, the blue color was very marked in all the chilled portion of the capillary tube. The experimenters were unable to determine positively whether this coloring was due to a mixed liquid of ozone and oxygen, or to a thin layer of liquid ozone on the inner walls of the capillary tube. When the ozone is liquefied in the capillary tube, it preserves its condition for a considerable time, even under atmospheric pressure, so that it can be examined and even withdrawn for a few moments from the chilled tube.—*Comptes Rendus*, xciv., 1249. C.

Franklin Institute.

HALL OF THE INSTITUTE, January 17, 1883.

The annual meeting of the Institute was held this evening at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

Present 86 members and 15 visitors.

The minutes of the last stated meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the meeting held January 10th, 14 persons had been elected members. He likewise presented the following resolutions passed by the Board at the meeting above named, viz.:

Resolved, 1. That the Board of Managers of the Franklin Institute has heard with great regret the proposition to transfer the Coast and Geodetic Survey of the United States from the Department of the Treasury to the Navy Department.

Resolved, 2. That a committee be appointed to prepare a remonstrance to Congress against the proposed transfer, and to present said remonstrance to the next meeting of the Institute for its action.

Resolved, 3. That the committee shall consist of three; and that the President be added thereto.

Upon which the President named the following to serve on the committee, viz.: William Sellers, William Helme, Dr. Persifor Frazer, and William P. Tatham.

On motion of Mr. Wm. Sellers, the regular order of business was suspended in order to consider the report of the committee, which was as follows:

The committee appointed under a resolution of the Board of Managers to prepare a petition and remonstrance to Congress, to be submitted to the Institute for its action, respectfully presents the following memorial:

To the Senate and the House of Representatives of the United States, Washington, D. C.:

Petition and remonstrance of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully represent—

That your petitioners have heard with great apprehension of the proposal to transfer the Coast and Geodetic Survey of the United States from the Treasury Department to the Navy Department, and would respectfully remonstrate against it for the following reasons:

1st. That the Survey was under the control of the Navy Department from 1819 to 1832, and that the results obtained were condemned by the then Secretary of the Navy, Mr. Southard, as unsatisfactory.

2d. That the existing organization of the Coast Survey, adopted after wise consideration, has produced magnificent results, with economy, rapidity and accuracy.

3d. That, in the words of the report of our committee, made in February, 1849, "the labors of the Survey ought to be (as they now are) divided among the Civil, Military and Naval talent of the country, in order to secure to each of these departments that knowledge of its processes and determinations which are equally required of them all."

4th. That it would be as unwise to put the Army officers under the Secretary of the Navy as to put the Naval officers under the Secretary of War, and that either arrangement would engender jealousies and suspicions which the present organization avoids.

5th. That the service being a peaceable one, the civil element should constitute the chief and permanent part of the organization, otherwise the occurrence of war, by calling the military branches to more congenial duties, would not only disorganize the service, but, for the time, would bring its operations to a close. To guard against such a misfortune and to insure that the Civil element should predominate, the Survey should remain under the Secretary of the Treasury, whose

department represents the interests of commerce, which it is the chief end of the Survey to subserve.

6th. That when, in 1848 to 1850, a similar suggestion was pending, the proposition fell of its own weight under the light of discussion (see "Congressional Globe," vol. 23), although chiefly supported by a reason which has now lost its force, namely, that the whole *object* of the Survey then, was hydrographical, the Geodetic branch of it being merely to supply a base of landmarks to connect and support the hydrography; whereas, now, the object of the Survey is to cover the territory of the United States from ocean to ocean, so as to connect both coasts, and therefore the peculiar service of the Navy bears a much smaller proportion to the whole.

7th. That it does not appear that the Treasury Department is dissatisfied with the existing arrangement for the service, nor that the officers of the Survey are discontented with their present head, nor that the existing organization has failed in any way to justify the wisdom of its founders.

Your petitioners therefore pray that your honorable body will maintain a system which has worked well for nearly fifty years, and not return to one which experience has condemned.

The Committee recommends the adoption of the following resolution:

Resolved, That this, the foregoing memorial shall be signed by the President, and that the Secretary shall attach the seal of the Institute thereto, and that it be duly forwarded.

Wm. Sellers,
Wm. Helme,
W. P. Tatham,
Persifor Frazer.

The report as read was unanimously adopted.

The Actuary then presented the following:

Annual Report of the Board of Managers.

The Board of Managers of the Franklin Institute of Pennsylvania, for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute during the year 1882, viz.:

Members.—During the year 131 new members have been added and 32 have resigned.

Treasurer's Report.—The following is a condensed summary of the report of the Treasurer for the year ending December 31, 1882:

Receipts.

Balance on hand January 1, 1882,	$1,325 64	
Cash received from investments sold out,	19,560 00	
Current receipts from all other sources,	14,789 00	
		$35,674 64

Payments.

Amounts re-invested,	$18,673 33	
All other current payments,	15,069 66	
Balance on hand Dec. 31, 1882,	1,931 63	
		35,674 64
Showing decrease of money invested,	$886 67	
Increase of cash balance,	606 01	
Balance the wrong way,		280 66

Library.—The average yearly increase in the money value of the Library, which was estimated in the last annual report of the Board at $2,000, has been fully maintained during the past year. Over 800 bound volumes were added, and a number of important serial publications were acquired or completed. The Board of Managers refers to the increasing importance of the Library with much gratification. The necessity, however, of additional room for the proper arrangement of the books, was felt more urgently than ever during the last year, and must continue to increase. The Board of Managers cannot pass this subject without alluding to the fact that the destruction by fire of any considerable portion of the Library, placed as it is in a building not fire-proof, would inflict great and perhaps irreparable loss upon the Institute and the community, since many of the volumes could not be replaced and cannot be found elsewhere.

Journal.—The JOURNAL, conducted as heretofore, by the Committee on Publication, with the assistance of the Secretary, was more than self-supporting during the past year. The Committee found it necessary to increase the edition printed, and the analysis of its report shows that the business of the JOURNAL has never been so large.

A general index to the JOURNAL is in preparation, and the Board feels assured that its value as a record of past progress for 59 years, will be greatly increased thereby.

Lectures.—At the beginning of the year, Prof. S. T. Skidmore completed a course of six illustrated lectures on "Mechanics," followed in the order named below, by Mr. Henry Trimble, with eight illustrated lectures on "Modern Chemistry;" Prof. M. B. Snyder, with four on "Astronomy;" Mr. Reuben Haines with four on "Applied Chemistry;" Mr. A. E. Outerbridge, Jr., with four on "Physics;" and Mr. D. S. Holman with one on "The Microscope and its Teachings." A number of lectures instructive and entertaining were also delivered under the auspices of the Phonetic Section.

The Autumn Course was opened by a course of four lectures by Prof. F. B. Maury, of the U. S. Signal Service, on "Meteorology," who was followed in the order named, by the following: Mr. Lorin Blodget, four lectures on the "Science of Statistics;" Prof. William H. Greene, four on "Explosives;" Mr. N. H. Edgerton, three on "Dynamo-Electricity and its Application to Industrial Uses;" and one illustrated "Christmas Lecture" by Mr. D. S. Holman. These lectures have been well attended. The Professors who were elected in 1881 have been of material help to the Committee in giving aid and advice in arranging the lecture courses.

The Committee on Instruction, with the approval of the Board, decided to continue the policy of issuing complimentary tickets to members for distribution to friends, which has been found to give general satisfaction. As noted in the annual report of last year, this arrangement makes the lectures practically free to the public.

Drawing School.—The Drawing School, under the able direction of Mr. William H. Thorne, has been very successful during the past year, and the results are highly gratifying. The attendance increased to such an extent as to require the division of the students into seven classes instead of four, as hitherto. The increase is shown by this statement: The number of pupils in 1882 was 332, as compared with 229 in 1881.

The accommodations not being sufficient for all these classes on the same evening, it became necessary to divide them, accommodating a portion on two evenings and the others on two alternate evenings.

Special attention has been paid by the Director and his assistants to bringing the school under a general system, whereby the students are classified and promoted according to their progress. This plan is found to favor both the improvement of the pupil and the efficiency of the teacher.

The instruction in drawing given by the Institute is in harmony with the practice of the shops, and our students upon graduation are fully qualified to use, interpret, and execute working drawings without having anything to learn or unlearn.

The Board commends the drawing school to the Institute as deserving of hearty support.

Sections.—During the past year an Electrical Section was established, which promises to become useful in promoting the interest of the Institute in this important branch of science. The Chemical Section has fully maintained the expectations formed of it, several useful and important papers having been read and discussed at its meetings and published in the JOURNAL. The interest in the Phonetic Section during the past year continued unabated.

Exhibitions.—The Committee having charge of this subject, conscious of the generally expressed desire that an exhibition should be held during the past year, gave the question careful consideration, and was brought to the conclusion respecting it, that it was inexpedient to hold a general exhibition, for the reasons, that there was no suitable building within reach available for the purpose, and that the condition of the finances of the Institute did not warrant the risk of erecting a special building for the purpose.

The suggestion has been made that a special exhibition, devoted to electricity and its applications in the arts, may be held during the present year, should such be the wish of the Institute at large.

The crowded condition of every branch of the Institute, which has been referred to in several previous reports of your Board of Managers, has continued to make itself felt as a serious inconvenience. After appropriating the rooms formerly devoted to the Models and Collection of Minerals, the rooms for the accommodation of the remaining departments, namely, the Library, the Lecture Room, and the Drawing School, are now so over-crowded as to tax to the utmost the ingenuity of the Committee in charge to make provision for the accomdation of books and students.

The necessity for new and enlarged accommodations, which was referred to last year, has come to be imperative.

To meet this necessity, the Board of Managers will, during the present year, make a renewed effort to obtain subscriptions to the building fund sufficient to insure the erection of a new and suitable building. The

members of the Institute are earnestly requested to aid the Committee having this work in charge, by every means in their power.

By order of the Board, WILLIAM P. TATHAM, *President.*

The Chairman of the Committee on Library presented in behalf of the Committee the following report, which was adopted without dissent, viz.:

The Committee on the Library respectfully reports—

The total number of bound volumes added by purchase to the Library during the past year was 262. Of these 158 volumes were purchased by the B. H. Moore Fund.

The number of unbound volumes added by purchase was 113; pamphlets, 13.

Donations were received of

Bound volumes,	302
Unbound volumes,	160
Pamphlets,	192

making the total of 564 bound, 273 unbound volumes, and 205 pamphlets added to the Library during the year 1882.

Binding.—244 volumes have been bound during the past year.

The total number of bound volumes in the Library, December 30, 1882, was 16,776.

Serial Publications.—Five of the most important serials in the Library have been completed, viz.:

"Armengaud's Publication Industrielle."
"Journal of the Royal Geographical Society."
"Wagner's Jahresbericht."
"Nouvelle Annales de la Construction."
"Revue Générale de l'Architecture."

The Committee has directed the completion of the "Philosophical Magazine" and "Brewster's Journal," which forms a part of this serial; also, the reports of the Pennsylvania Railroad Company, and the proceedings of the "American Railway Master-Mechanics' Association."

Duplicates.—88 volumes have been disposed of during the year, at an average of $1.00 per volume.

Exchanges received for the JOURNAL OF THE INSTITUTE number 208.

Number of volumes taken out by members during the year, 2000.

CHARLES BULLOCK, *Chairman.*

Philadelphia, January 16, 1883.

The Trustee of the Pennsylvania Museum and School of Industrial Art presented the following report which was received and adopted, viz.:

PHILADELPHIA, January 17, 1883.

To the President and Members of the Institute.

Your Trustee in the Pennsylvania Museum and School of Industrial Art, at the close of another year, has the honor to report, that never in the history of the Museum has there been so gratifying an attendance as that for 1882, more than one hundred and fifty-nine thousand visitors having been within its walls, a very considerable increase over the previous year. Whatever a few people may think of the wisdom of establishing such an institution in our city, and its educational value, there can be no doubt of its popularity with the masses and the great interest they take in its collections.

The inventory of the Museum has been completed and a slip catalogue designates the exact location of any object. Quite a number of very interesting things have been loaned to the Museum, some of them of very great value, while Mrs. Bloomfield Moore continues her gifts to the collection in honor of her husband, and the room containing them is one of the most attractive features of the exhibition.

It is part of the plans of the Trustees to store a portion of the less interesting objects of the Museum in the basement of the building, and to use the room thus gained for additional cases, and to have in the spring, lectures delivered on art subjects; the running of frequent Park trains having rendered attendance thereat very easy and at trifling expense to visitors. The plan has been tried with marked success at the Horticultural building, in the Park, and the course of lectures on botany, delivered under the auspices of the American Philosophical Society, has been well attended.

The Industrial Art School, which is so important a part of the work of the Museum, has been carried on at 1709 Chestnut street, and the attendance at night has been all the rooms would accommodate. About ninety pupils have received very thorough instruction from their Principal, Mr. L. W. Miller, and his able assistant in drawing—the foundation of all art—painting and modelling. The Committee in charge of the School has aimed in the progressive three years' course not only to exalt the standard of instruction, but to make it as thorough as possible in the various constructive and decorative arts,

that its diploma might mean something, as it could only be attained by ability and hard work. The Chairman of the Committee on Instruction, Mr. Frederick Graff, has constantly urged this, and he has been ably seconded by Mr. Miller, who has labored unceasingly, and whose heart has been in the work.

The few graduates of the School have not had the slightest difficulty in getting remunerative positions, showing the need of such a School, especially as a training one for teachers, and the Trustees are unanimous in thinking that when the prospect is so bright, the want of funds should not limit the usefulness of the Museum and School. Some progress has been made to a suitable endowment. About $47,000 have been contributed, a considerable portion given with the condition that fifty thousand shall be raised, and as the income is much wanted to carry on the School, all interested in art education and the industrial prosperity of our city, should see that it is speedily done.

ISAAC NORRIS, M. D.

The Secretary, on behalf of the Chairman of the Committee on Science and the Arts, reported that the Committee had recommended the award of the John Scott Legacy Premium and Medal, to the following:

To Henry Ashford, of Philadelphia, for his "Apparatus for Attaching and Detaching Boats."

To D. K. Miller, of Philadelphia, for his "Self-Locking Padlock."

And to B. H. Kemble, of Philadelphia, for his "Improvement in Vehicle Axles and Boxes."

He reported that the above recommendations had been duly advertised in the JOURNAL for the period of three months, in accordance with the Committee's regulations, and that no objections thereto had been received.

The above recommendations were thereupon taken up and voted upon separately, being in each case approved without dissent.

The tellers of the annual election held this day, between the hours of 4 and 8 P. M., made their report, whereupon the President announced the following as the result, viz.:

President (to serve one year), William P. Tatham.

Vice President (to serve three years), Frederick Graff.

Secretary (to serve one year), William H. Wahl.

Treasurer (to serve one year), Samuel Sartain.

Managers (to serve three years), E. J. Houston, William H. Thorne, Persifor Frazer, Enoch Lewis, William Helme, Charles H. Banes, Frederick Fraley, and John J. Weaver.

Auditor (to serve three years), William A. Cheyney.

On motion of Mr. Burk, a vote of thanks to the tellers for their services was unanimously adopted.

A ballot was thereupon taken for the election of a Trustee of the Pennsylvania Museum and School of Industrial Art, which resulted in the choice of William H. Wahl.

Mr. C. John Hexamer then read a paper on "Dust Explosions in Breweries," which was illustrated by means of a number of lantern views. The paper appears in the JOURNAL for February.

Mr. Robt. Grimshaw gave a summary of the results he had obtained in determining the influence of "Pulley Diameter on the Driving Power of Belts." Mr. Grimshaw illustrated his subject graphically, and claimed from a comparison of a large number of experiments, to be warranted in announcing results at variance from those of Morin and others. The paper has been referred for publication.

Dr. Constantine Fahlberg, by invitation, gave an account of a new sweet substance which had been discovered in the course of some investigations upon coal tar derivatives. The speaker described the process of producing the new body, and exhibited specimens of it and its salts. He defined it to be benzoic sulphinide (or anhydrosulphaminebenzoic acid). Its most distinguishing characteristic is its intense sweetness, being much sweeter than cane sugar. An abstract of Dr. Fahlberg's remarks will appear in the JOURNAL.

The Secretary, in his report, gave a review of scientific and industrial progress during the year 1882, (see page 135), and a description of the following inventions:

A "Revolution Counter," made by the Crosby Steam Gauge & Valve Co, Boston. This registers on a ratchet-toothed graduated dial-plate the number of strokes of a cross-head or any other reciprocating piece of machinery. It is especially intended for use with the steam-engine indicator on locomotives and other very high-speed engines, where the ordinary devices would either break or fail to record all the strokes.

A "Substitute for Turn Tables," designed by F. Lawrence, of Philadelphia. The carriage is intended to carry ladles of melted iron, which must be carried quickly and without spilling. Instead of a turn table a very short curve may be used, and a short curved length of supple-